

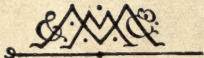
ELEMENTARY CHEMISTRY OF AGRICULTURE

S. ALLINSON WOODHEAD





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OF AGRICULTURE



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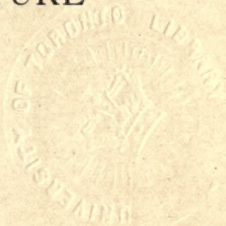
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ELEMENTARY CHEMISTRY OF AGRICULTURE

BY

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PREFACE

THE author of an introductory book dealing with an applied science like agricultural chemistry is faced at the outset with the difficulty as to how far he may assume a knowledge of preliminary scientific principles by his readers. Given an acquaintance with the elements of physics, chemistry and botany, or some familiarity with the methods of practical chemistry, it is relatively easy to construct a profitable course illustrating their applications in the farm and field. Unfortunately, this knowledge is often not possessed by pupils who wish to study agricultural chemistry, either because they have not received any instruction in elementary science, or because they have forgotten what they knew. It is impossible always to insist upon a preliminary course in which fundamental facts and principles are presented in logical sequence. What can be done, however, in the absence of such a course, or for students who require memorabilia of chemistry, is to describe a few essential operations and ideas at the beginning, and then to deal with others as they are needed in the course.

This is the plan adopted in the present book; and it is hoped by it that the experiments will be found instructive and the descriptive text intelligible by agriculturists interested in the chemistry of the farm, as well as by serious students who intend to follow the subject to more advanced stages from the foundation here provided. An endeavour has been made to give adequate attention

to matters of interest and practical value, and to stimulate a desire on the part of the reader to understand the "Why" and "Wherefore" of particular operations as well as the "How" and "When."

Many of the analytical results given in the text are from analyses carried out in the author's laboratory; but in dealing with such a wide subject, it has been necessary to use values in standard works and current literature dealing with special branches of the subject. To the various works by Hall (*Soils, Manures, Feeding of Stock and Crops*), Russell (*Soils, Manures, and Rothamsted Reports*), Kellner (*Scientific Feeding of Animals*), Potter (*Agricultural Botany*), and Percival (*Agricultural Botany and Bacteriology*), the author is specially indebted.

To Prof. R. A. Gregory and Mr. A. T. Simmons the writer desires to express his sincere thanks for their valuable suggestions and criticisms at all stages during the preparation of the work. Without such generous help it is not too much to say that the book would never have been completed. For its imperfections incident to a small work of such wide range, the author accepts full responsibility.

S. A. WOODHEAD.

UCKFIELD, 1918.

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CHAPTER I.

ELEMENTARY PRINCIPLES AND LABORATORY TESTS.

[Pages 1 to 19 are to be used for reference ; they may be omitted by readers who have already studied Elementary General Chemistry.]

AN elementary knowledge of the facts and principles of general chemistry is essential to the profitable study of such a branch of applied science as Agricultural Chemistry. It is possible to illustrate a general course of chemistry by its special applications in agriculture, but within the limitations of this book, such a combination cannot be presented satisfactorily. In this volume, therefore, it is assumed that the student has received some preliminary instruction in chemistry ; or if not, that during the course in agricultural chemistry, lessons are given upon such general points as must be known in order that the special aspects of the subject may be understood. For the sake of those students who have received instruction in elementary chemistry, but whose recollection of the details of their earlier course may not be very fresh, some of the main points required for the study of agricultural chemistry are summarized in this introduction. A few elementary tests are also given as examples of the practical work bearing upon subjects discussed in the book.

The purpose of this Introduction is to make the book self-contained, so far as that is possible, and thus to obviate the necessity for frequent reference to notes or text-books of general chemistry. It is not suggested

that this summary should take the place of a preliminary short course, though it may be used as such if sufficient explanation and guidance are given in the class-room and the laboratory. The main object of the Introduction is to recall fundamental points rather than to attempt to present them in a form suitable for students who have not previously received any training in chemistry. Nothing short of a good preliminary course in theoretical and practical chemistry will enable a student to derive the fullest advantage from instruction in the applications of the science to agriculture, or any other industry.

ELEMENTARY CHEMISTRY.

Natural Science is the study of natural objects, and embraces in its widest sense everything which has material existence. Those branches of it treating of animals and plants are known respectively as zoology and botany, or collectively as biology. Geology treats of the structure and history of the earth; while chemistry is the science which deals with the composition of substances and the changes they undergo.

Elements and Compounds. All substances are either simple, that is, elementary, or compound. Of simple substances between eighty and ninety are known. They are called **elements** or elementary matter, and so far as can be ascertained, they cannot be split up into simpler substances. When two or more elements combine, **compounds** are produced. The smallest particle of an element which can enter into, or be driven out of a compound, is known as an **atom**. While the atoms of the same element are of the same weight, the atoms of different elements vary in weight.

The first letter, or two letters, of the names of an element are used in chemistry to indicate the element, and an atom

of that element. These letters are known as **symbols**. In the second column of the following table of the important elements the symbols are given.

Table of Important Elements.

Name.	Symbol.	Solid, Liquid or Gas.	Metal or Non-metal.	Atomic weight to nearest whole number.
Aluminium -	Al	Solid	Metal	27
Arsenic -	As	"	Intermediate	75
Calcium -	Ca	"	Metal	40
Carbon -	C	"	Non-metal	12
Chlorine -	Cl	Gas	"	35.5
Copper -	Cu	Solid	Metal	63.5
Gold -	Au	"	"	197
Hydrogen -	H	Gas	Non-metal	1
Iodine -	I	Solid	"	127
Iron -	Fe	"	Metal	56
Lead -	Pb	"	"	207
Magnesium -	Mg	"	"	24
Mercury -	Hg	Liquid	"	200
Nitrogen -	N	Gas	Non-metal	14
Oxygen -	O	"	"	16
Phosphorus -	P	Solid	"	31
Platinum -	Pt	"	Metal	195
Potassium -	K	"	"	39
Silicon -	Si	"	Non-metal	28
Silver -	Ag	"	Metal	108
Sodium -	Na	"	"	23
Sulphur -	S	"	Non-metal	32
Tin -	Sn	"	Metal	119
Zinc -	Zn	"	"	65

Sometimes the letters forming the symbol are taken from the Latin name of the element to avoid confusion with other elements beginning with the same letter, thus Fe (from Latin *ferrum*) stands for iron, because iodine is represented by I.

The properties of atoms. The atoms of elements are of

the same size. The exact weights of atoms are not known, but by taking the atom of a very light element, known as hydrogen, as unity, the relative weights of other atoms have been ascertained; thus, the atom of the element oxygen is nearly sixteen times heavier than the atom of hydrogen. The figure indicating the number of times an atom of an element is heavier than an atom of hydrogen is known as the **atomic weight** of that element.

When two elements are mixed they may remain so, thus exhibiting the properties of both elements; or they may combine chemically and form an entirely new substance—a **chemical compound**. A mixture may have its components in any proportion, but a chemical compound always has its constituent elements present in one proportion, due to the fact that each element possesses a definite power to combine with or displace other elements. This power is known as **valency**.

The valency of an element is determined by the number of hydrogen atoms it can displace or with which it can combine. The valency of oxygen is 2; nitrogen, 3; and carbon, 4. The compounds produced with hydrogen in these cases are H_2O (water), NH_3 (ammonia), CH_4 (marsh gas). Water always consists of 2 atoms of hydrogen combined with 1 of oxygen; ammonia of 1 atom of nitrogen combined with 3 of hydrogen; and marsh gas of 1 atom of carbon combined with 4 of hydrogen.

When atoms of the same element combine a **simple molecule** is produced. Thus O_2 stands for a molecule of oxygen.

When atoms of different elements combine a **compound molecule** is produced; for example, 2 atoms of hydrogen chemically combine with 1 atom of oxygen to form 1 compound molecule, water, written H_2O .

A **molecule** is defined as the smallest particle of any substance capable of free existence and is produced by the union of like or unlike atoms.

It will be noticed that small figures written below symbols indicate the number of atoms represented by that symbol. Thus H_2O means 2 atoms of hydrogen combined with 1 of oxygen (the figure 1 is never written), forming one molecule of water. If two molecules have to be represented, the 2 is placed in front, thus, $2\text{H}_2\text{O}$.

Although only between 80 and 90 elements are known, the compounds which can be produced from them are very numerous. It is impossible for any one person to study all the compounds; therefore the subject is subdivided. That branch dealing with agricultural products is known as agricultural chemistry; there is also a chemistry of soils, of manures, of feeding stuffs, and of dairy produce.

Formulae. When two or more atoms combine to form a chemical compound, the simplest collection of symbols which will accurately represent the compound is known as a **formula**. For example, the formula for sodium nitrate, commonly called nitrate of soda, is NaNO_3 . This formula expresses the fact that 1 atom of sodium, 1 of nitrogen, and 3 of oxygen are present in 1 molecule of nitrate of soda. The relative weight of a molecule compared with an atom of hydrogen is known as its **molecular weight**, and is the sum of the atomic weights of its component elements.

Thus, the molecular weight of nitrate of soda (NaNO_3) is 85; that is, a molecule of nitrate of soda is 85 times as heavy as an atom of hydrogen. The weight is calculated as follows:

Sodium (Na)	-	at. wt.	23
Nitrogen (N)	-	"	14
Oxygen (O)	-	"	16
" (O)	-	"	16
" (O)	-	"	16
			85

Thus, 85 parts by weight of nitrate of soda contain 23 of sodium ; 14 of nitrogen ; and 48 of oxygen.

In a similar way it is possible to ascertain the proportion in which elements are present in any compound, provided the formula is known and also the atomic weights of the constituent elements.

Classification of elements. Careful examination of the elements has shown that many of them can be grouped under two heads, known as metals and non-metals.

Metals often have metallic lustre, or a shining brightness of their own ; they are generally good conductors of heat and electricity, and are mostly solids at ordinary temperatures, although one, mercury, is liquid. **Non-metals** are generally without metallic lustre, and are bad conductors of heat and electricity. Some are solids, while others are liquids, or gases.

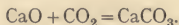
The important non-metals are oxygen, hydrogen, nitrogen, chlorine, iodine, sulphur, phosphorus, carbon, and silicon, while the important metals are silver, gold, mercury, lead, copper, tin, iron, zinc, aluminium, calcium, magnesium, potassium, and sodium. There are a few, such as arsenic, which have intermediate properties partaking of the nature of metals and non-metals. No strict line can really be drawn between the two classes.

Acids, Bases, and Salts. When the element oxygen combines with metals, **oxides** are produced, which have properties quite distinct from the compounds formed when oxygen combines with non-metals. In chemical language, oxides of metals which dissolve in water are **basic** or **alkaline** ; while oxides of non-metals are **acid** or produce acids on addition of water. An alkaline oxide will, if allowed to act upon an acid oxide, destroy its properties, that is, will **neutralize** it.

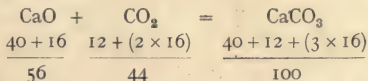
The compound produced when a basic oxide neutralizes an acid oxide is known as a **salt**. For example, oxide of

calcium (CaO), if acted upon by carbon dioxide (CO₂), results in the formation of carbonate of calcium (CaCO₃), commonly called chalk, or limestone.

The chemical representation of this reaction is usually in the form of an equation :



This equation is read not as an algebraic equation, but as follows : oxide of calcium reacts with carbon dioxide to form carbonate of calcium. It may be mentioned that reactions such as the above usually take place in the presence of water, but this may here be disregarded. Not only does the above equation represent the reaction between the oxides, but it also shows in what proportion by weight they react. Re-writing the equation and placing below the symbol of each element its atomic weight, we have :



Thus, 56 parts by weight of calcium oxide (lime) react with 44 parts of carbon dioxide to form 100 parts by weight of calcium carbonate.

Whenever elements or compounds react to form other compounds, or whenever compounds are decomposed, the reaction or decomposition can always be represented by an equation, which thus serves not only to represent the reaction, but also the proportion by weight of the elements or compounds taking part in the reaction.

QUALITATIVE ANALYSIS.

Qualitative tests are here given for the more important metals, non-metals, acids, and bases present in soils,

manures, feeding stuffs, and water. For convenience, the tests may be subdivided into :

(1) Tests for constituents present in carbon compounds (organic matter) ;

(2) Tests for important constituents present in inorganic compounds (mineral matter and ash).

Qualitative organic analysis. The important elements present in organic matter are carbon, hydrogen, oxygen, and generally also nitrogen, phosphorus, and sulphur. Of these, it is necessary to be able to detect carbon, because its presence decides whether an unknown substance is organic or not, while nitrogen and phosphorus are so very important as constituents of plant foods and feeding stuffs that a knowledge of the chief tests for them is really essential.

Tests for carbon. 1. Place a small portion of the substance in a crucible, or, better still, in a small hard glass test-tube, and heat it gently at first, finally heating strongly. If the substance is organic it chars and combustible gases are evolved.

2. Mix a little of the substance in a test-tube with four or five times its bulk of copper oxide, and heat the mixture strongly. Gases are given off. Test for carbon dioxide by holding a glass rod which has been dipped in lime water at the mouth of the tube. If the lime water turns milky, CO_2 is present, and the substance is organic.

3. Sulphuric acid chars many organic substances when the two are heated together.

Tests for nitrogen. 1. Heat a small portion of the substance in a test-tube with soda lime. If nitrogen is present ammonia will be evolved, recognized by its smell and by turning moistened reddened litmus paper blue.

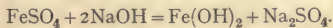
2. Heat about 2 grams of the substance in a flask of resistance glass with 20 c.c. of concentrated sulphuric acid until the solution is practically free from carbon particles.

After cooling, dilute carefully with 100 c.c. of water. Render the solution alkaline with caustic soda, and distil into very weak acid. The acid is neutralized either partially or entirely by the ammonia evolved.

The explanation of these reactions is as follows: The sulphuric acid acts upon the nitrogenous organic matter, producing sulphate of ammonia, $(\text{NH}_4)_2\text{SO}_4$. This when acted upon by caustic soda evolves ammonia, which when passed into the weak acid neutralizes it, and may of course render the solution alkaline if there is an excess of ammonia over the weak acid.

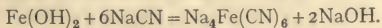
3. Heat a small portion of the substance in a test-tube with a small piece of metallic sodium, or potassium. (*Be very careful in using these dangerous substances.*) Break the tube by dipping it while hot in a small beaker of cold water. Stir the mixture well; then filter, and test the filtrate as follows. Add a few drops of ferrous sulphate solution; then boil and acidify with dilute hydrochloric acid. A blue precipitate of Prussian blue is produced if nitrogen was originally present.

The explanation is as follows. The sodium produces sodium cyanide (NaCN). The ferrous sulphate when added becomes, ferrous hydrate $\text{Fe}(\text{OH})_2$, due to the caustic soda produced (on dissolving the excess of sodium in water) reacting with the ferrous sulphate as follows:



Ferrous
hydrate.

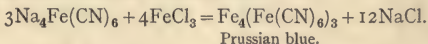
The ferrous hydrate reacts with the sodium cyanide to form sodium ferrocyanide, $\text{Na}_4\text{Fe}(\text{CN})_6$.



Sodium
ferrocyanide.

The addition of HCl at this stage produces ferric chloride, and this reacting with the sodium ferrocyanide

produces Prussian blue, $\text{Fe}_4(\text{Fe}(\text{CN})_6)_3$; the equation representing this reaction is as follows :

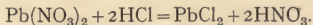


Tests for phosphorus. Fuse a small portion of the substance with a mixture of equal proportions of sodium carbonate and potassium nitrate. Dissolve the fused mass in water. Add nitric acid until the solution is decidedly acid. Filter; then warm the filtrate with ammonium molybdate solution. A yellow precipitate indicates phosphorus.

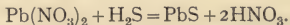
Qualitative inorganic analysis. For convenience, the tests employed may be divided into (a) Tests for metals, (b) Tests for acids.

Tests for metals. The metals of importance agriculturally are: lead, copper, arsenic, iron, aluminium, calcium, magnesium, potassium, and ammonium; while important acids are carbonic, sulphuric, nitric, hydrochloric, phosphoric, boric, oxalic, acetic, and silicic.

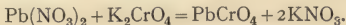
Lead. 1. Hydrochloric acid produces in cold solutions of lead salts a white precipitate of lead chloride, PbCl_2 , soluble in boiling water, but insoluble in ammonium hydroxide.



2. Sulphuretted hydrogen produces a black precipitate of lead sulphide, PbS



3. Potassium chromate gives a yellow precipitate of lead chromate soluble in nitric acid.

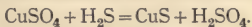


Lead chromate.

Copper. 1. Ammonium hydroxide gives a greenish blue precipitate of copper hydroxide, $\text{Cu}(\text{OH})_2$, which dissolves

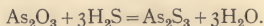
on adding excess of ammonium hydroxide to form a deep blue solution.

2. Hydrogen sulphide produces a black precipitate of copper sulphide soluble in hot nitric acid.

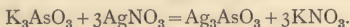


Copper
sulphide.

Arsenic. *Arsenites.* 1. Hydrogen sulphide produces in acid solutions a yellow precipitate of arsenic trisulphide, (As_2S_3).



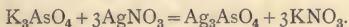
2. Silver nitrate produces in *neutral* solutions a yellow precipitate of silver arsenite soluble in ammonium hydrate.



Silver arsenite.

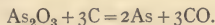
Arsenates. 1. Hydrogen sulphide produces no precipitate until it has been passed into a solution of an arsenate for some time. The hydrogen sulphide finally reduces the arsenate to arsenite when the reaction mentioned under Arsenites (1) takes place.

2. Silver nitrate produces with solutions of arsenates a brownish precipitate of silver arsenate.



Silver arsenate.

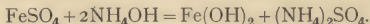
3. Arsenites and arsenates when heated with dry charcoal are reduced to the metallic condition. If an arsenite or arsenate be heated in a narrow tube and the volatilized arsenic be passed over heated charcoal, the metal sublimes on the cooler portions of the tube, forming a metallic mirror.



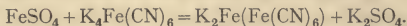
The presence of excess of air will cause the metal to oxidize, forming As_2O_3 , which separates as octahedral crystals on the cooler portion of the subliming tube.

If, therefore, the portion of the tube containing the mirror of arsenic be heated in a small dry test-tube, crystals of arsenic trioxide will be obtained.

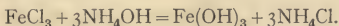
Iron. 1. *Ferrous salts.* Ammonium hydrate produces a dirty greenish-white precipitate of ferrous hydrate, $\text{Fe}(\text{OH})_2$, which soon changes to a brown precipitate due to oxidation to ferric hydrate.



2. Potassium ferrocyanide produces a white precipitate of potassium ferrous ferrocyanide, $\text{K}_2\text{Fe}(\text{Fe}(\text{CN})_6)$.

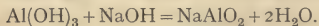
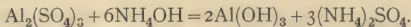


1. *Ferric salts.* Ammonium hydroxide produces a reddish-brown precipitate of ferric hydroxide, $\text{Fe}(\text{OH})_3$, insoluble in excess.



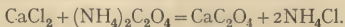
2. Potassium ferrocyanide gives a deep blue precipitate of Prussian blue, $\text{Fe}_4(\text{Fe}(\text{CN})_6)_3$.

Aluminium. 1. Ammonium hydroxide gives a white *gelatinous* precipitate of aluminium hydroxide, $\text{Al}(\text{OH})_3$, soluble slightly in excess of ammonium hydroxide. If potassium or sodium hydroxide be used in place of ammonium hydroxide, the precipitate is readily soluble in excess of the reagent, forming potassium or sodium aluminate.



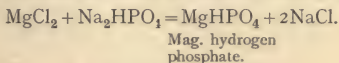
Sodium aluminate
(Soluble).

Calcium. 1. Ammonium oxalate produces a heavy white precipitate of calcium oxalate soluble in hydrochloric acid, but insoluble in acetic acid.

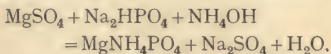


Calcium
oxalate.

Magnesium. 1. Sodium phosphate produces a white precipitate of magnesium hydrogen phosphate.

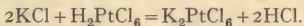


If ammonium hydrate and ammonium chloride are added at the same time as the sodium phosphate, magnesium ammonium phosphate is precipitated.

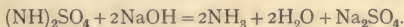


(*N.B.*—The object in adding the ammonium chloride is to prevent the precipitate of magnesium hydroxide.)

Potassium. 1. Platinum chloride produces in neutral or slightly acid solutions of potassium salts a golden or orange-coloured precipitate of potassium platinum chloride, K_2PtCl_6 .

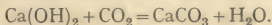


Ammonium. 1. All ammonium compounds when boiled with a solution of caustic soda evolve ammonia, which can be recognized by its pungent smell and by colouring reddened litmus blue.

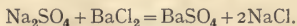


2. Nessler's solution gives a yellow colouration with very dilute solutions of ammonium salts and a brown precipitate with strong solutions.

Acids. **Carbonic acid,** H_2CO_3 . All carbonates effervesce when treated with mineral acids and also with most organic acids. Carbon dioxide (CO_2) is evolved; and its presence may be proved by noting its power to turn lime water milky, due to formation of calcium carbonate, CaCO_3 .



Sulphuric acid, H_2SO_4 . Barium chloride, $BaCl_2$, gives a white precipitate of barium sulphate, $BaSO_4$, insoluble in hydrochloric acid.

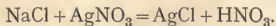


Nitric acid, HNO_3 . 1. Nitrates, when ignited, yield brown fumes of nitrogen peroxide, NO_2 .

2. If concentrated sulphuric acid is poured carefully down the sides of a test-tube containing a mixture of ferrous sulphate and a nitrate, a brown ring is produced where the two liquids meet.

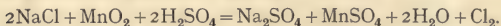
3. A solution of indigo in concentrated sulphuric acid is bleached by the presence of a nitrate. If, therefore, a solution of indigo in sulphuric acid is added to a solution of a nitrate, the blue colour is changed to yellow.

Hydrochloric acid, HCl . 1. Silver nitrate produces a white curdy precipitate of silver chloride soluble in ammonium hydroxide but insoluble in nitric acid.

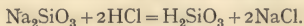


Silver
chloride.

2. Chlorides when treated with manganese dioxide and sulphuric acid evolve chlorine (Cl_2), recognized both by its greenish-yellow colour and by its smell.



Silicic acid, H_2SiO_3 . 1. If to a soluble silicate such as silicate of soda a dilute mineral acid (hydrochloric acid) is added, the silicic acid will, on concentrating the solution by evaporation, be deposited as a jelly-like mass.



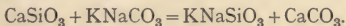
Silicic acid.

On evaporating the mixture to dryness, the silicic acid is decomposed, silica (SiO_2) and water being produced.



Silica is insoluble and as such can be separated from any soluble compounds present.

2. Insoluble silicates if fused with fusion mixture, KNaCO_3 , give soluble silicates.

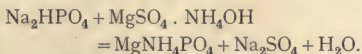


Pot. sod.
silicate.

Test 1 may then be applied to the soluble silicates.

Phosphoric acid, H_3PO_4 . 1. Ammonium molybdate gives a yellow precipitate of ammonium phosphomolybdate, $12\text{MoO}_3 \cdot (\text{NH}_4)_3\text{PO}_4$, which is insoluble in nitric acid but soluble in ammonium hydroxide.

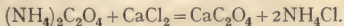
2. Magnesia mixture gives with solutions of phosphates a white crystalline precipitate of magnesium ammonium phosphate, MgNH_4PO_4 , insoluble in ammonium hydroxide but soluble in acids.



Boric or boracic acid, H_3BO_3 . If to any borate concentrated sulphuric acid is added until the mass is pasty, and then a little alcohol, the alcohol on being ignited burns with a flame tinged with green.

2. Borates if treated with dilute hydrochloric acid, yield boric acid which colours turmeric paper a decided brown. This brown colour is changed to blue or black on touching with caustic soda.

Oxalic acid, $\text{C}_2\text{H}_2\text{O}_4$. 1. Calcium chloride produces in neutral or alkaline solutions of oxalates a white crystalline precipitate of calcium oxalate soluble in hydrochloric or nitric acid but insoluble in acetic acid.



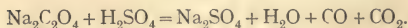
Calcium
oxalate.

2. Oxalates when warmed with concentrated sulphuric

acid decompose, carbon monoxide (CO) and carbon dioxide (CO₂) being evolved.



or



Acetic acid, C₂H₄O₂. Acetates when warmed with concentrated sulphuric acid smell of vinegar (acetic acid), and when acetates are heated with alcohol and sulphuric acid the odour of ethyl acetate, which is pleasant and characteristic, is easily detected.

Qualitative testing of soils. 1. Heat a small portion of any fertile soil in a test-tube. Note that water vapour is driven off.

2. Ignite 5 grams of the said soil in a porcelain crucible or dish. The substance chars to some extent, and ultimately a greyish-white ash is obtained.

3. Dissolve this ash in 100 c.c. of dilute HCl, and boil it for ten minutes. Filter the solution and wash the insoluble matter on the filter paper with hot water until free from acid. Test the solution thus obtained for iron, aluminium, calcium, phosphoric acid, silicic acid, nitrogen, and potassium as follows.

4. Take about 50 c.c. of the solution and evaporate to dryness on the water bath. When visibly dry, heat at a low temperature for five minutes. Then cool the dish or beaker. Add 25 c.c. dilute HCl and warm for ten minutes. Filter. The insoluble matter on the filter is silica obtained from the soluble silicates present or the insoluble silicates decomposed by the HCl added to the soil.

To the filtrate add ammonium hydroxide until alkaline. Iron and aluminium are precipitated together, iron as brown ferric hydrate, Fe(OH)₃, and aluminium as aluminium hydroxide, Al(OH)₃. Filter. To the alkaline filtrate

add ammonium oxalate. A white crystalline precipitate indicates calcium (the precipitate would of course be calcium oxalate, CaC_2O_4).

Evaporate the filtrate obtained from the calcium oxalate to dryness and ignite carefully. Dissolve the residue in hot water. Filter. Add a few drops of hydrochloric acid and 2 c.c. of platinum chloride solution. Evaporate on the water bath until just pasty. Wash with 5 c.c. of alcohol three times, pouring off the alcohol after each washing. If a precipitate remains which is orange-coloured, potassium was originally present in the soil.

To another portion of the original solution add 20 c.c. of a solution of ammonium molybdate. A yellow precipitate indicates phosphoric acid.

Nitrogen may be tested for in soils as described under "Test for Nitrogen; Qualitative Organic Analysis," pp. 8 to 10.

Testing Manures. Manures may be tested for nitrogen, phosphoric acid, and potash exactly as described under soils. If the manure is not organic the preliminary ignition may be omitted.

Testing Water. 1. Evaporate 50 c.c. of tap water to dryness in a clean platinum or porcelain dish. Ignite the residue and note if it chars. Good waters give residues which do not char on heating. Do the same with rain water and drainage water, and note the results.

2. Add to 50 c.c. of water a few drops of potassium chromate and then drop by drop a solution of silver nitrate. If a white precipitate is produced, chlorides are present in the water, and if the addition of the silver nitrate be continued until all the chlorides are precipitated, insoluble silver chromate (brick-red in colour) will be produced. It is thus possible by using potassium chromate as indicator, to tell when all the chlorides are precipitated, and as a consequence it is possible by using a

solution of silver nitrate of known strength to ascertain the amount of chlorine actually present.

3. To 50 c.c. of the water add a few drops of hydrochloric acid and then 5 c.c. of barium chloride solution. A white precipitate indicates sulphuric acid (sulphates).

4. To 50 c.c. of the water add 5 c.c. of dilute (0.04 per cent.) potassium permanganate solution and 5 c.c. of dilute sulphuric acid. If the permanganate solution is decolourized on standing four hours, the water contained much organic matter (either animal or vegetable matter). This was formerly a rough test for the purity of drinking water.

5. Distil 500 c.c. of water until only 300 c.c. are left. Collect the distillate in 50 c.c. fractions. To each 50 c.c. add 2 c.c. of Nessler's solution. A yellow colouration indicates ammonia. Bad waters contain a high proportion of ammonia either as free ammonia or combined with nitrogen. Combined nitrogen can be liberated as ammonia by boiling the water with an alkaline solution of potassium permanganate. To the 300 c.c. remaining in the retort, add 50 c.c. of a solution of alkaline potassium permanganate and continue the distillation. Test the distillate for ammonia by means of Nessler's solution. A strong yellow colour or brown precipitate points to the water having contained nitrogenous organic matter (animal or vegetable).

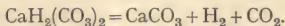
6. To 50 c.c. of water add 5 c.c. of ammonium oxalate solution. A white precipitate indicates the presence of calcium in the form of lime.

7. Obtain a standard solution of soap (1 c.c. = 1 milligram of calcium chloride). To 70 c.c. of water in a stoppered bottle add the soap solution gradually until on shaking vigorously a lather is produced, which is permanent five minutes. The number of c.c. of the standard soap solution required to produce this permanent lather is known as the "total hardness" of the water.

Hard waters therefore require much soap to produce a lather ; therefore soft water should be used for laundry purposes.

If another 70 c.c. of the water is first boiled for ten minutes and then filtered, and the resulting filtrate tested with the soap solution, it will be noticed that the hardness is lower, due to the boiling having precipitated some of the salts responsible for the hardness. Hardness which can be got rid of by boiling is known as "temporary hardness," while the remaining hardness is known as "permanent hardness."

Temporary hardness is sometimes due to salts similar to calcium bicarbonate, but generally to this salt alone. Calcium bicarbonate, $\text{CaH}_2(\text{CO}_3)_2$, is a soluble salt ; but on boiling it decomposes into insoluble calcium carbonate CaCO_3 , carbon dioxide CO_2 , and water H_2O .



Permanent hardness is due to salts such as calcium sulphate, calcium chloride, and similar magnesium salts ; and these are not precipitated on boiling.

QUESTIONS.

1. What do you know of the scope of chemistry ?
2. Define atom, molecule, atomic weight, and molecular weight.
3. Enumerate the uses of a chemical equation.
4. Calculate the weight of nitrogen present in 34 lb. of ammonia (NH_3) ; atomic weights, $\text{N} = 14$, $\text{H} = 1$.
5. What do you understand by the term valency ?
6. What metals are of importance agriculturally ?
7. How would you test for copper in a mixture of copper sulphate and iron sulphate ; and how would you detect iron sulphate as an adulterant of copper sulphate ?

8. A sample of manure (organic) is said to contain potash. State briefly how you would proceed to prove its presence.

9. How would you estimate the percentage of total solid matter in a sample of river water (a) in solution, (b) in suspension ?

10. What is meant by the hardness of water ? What are temporary hardness and permanent hardness ? How are they estimated ?

11. What tests would you apply to a sample of drinking water to prove the presence of (a) calcium salts, (b) magnesium salts, (c) ammonia, (d) chlorides, (e) sulphates ?

12. How would you prove the presence of phosphoric acid in (a) an organic manure, (b) an inorganic salt ?

13. State briefly how the percentage of ash may be estimated in a feeding stuff.

14. Describe clearly how you would detect the presence of nitrogenous matter in any farm food.

15. What impurities would you expect to find in (a) rain water, (b) drainage water ?

CHAPTER II.

THE BEGINNINGS AND DEVELOPMENT OF A CHEMISTRY OF AGRICULTURE.

Early interests. The problems connected with the cultivation of land, the manuring of crops, and the breeding and rearing of animals, have engaged the attention of mankind for centuries. In man's primitive state his interest was no doubt centred in these matters, in virtue of the fact that his very existence was dependent upon them. What knowledge he possessed was applied in a very practical manner, for the purpose, namely, of providing himself and his family with food. In those early times, there does not appear to have been any marked tendency or necessity to enquire "Why?" when the same object could be attained by the simpler expedients of "how" and "when."

As civilization advanced, man began to reason why certain operations were carried out, and also to study the causes of existing phenomena; thus laying the foundation of Natural Philosophy or Science, that is, a knowledge of principles. Such enquirers or investigators were known as philosophers—or lovers of wisdom—and their representatives at the present day are experimental philosophers, or men of science, who use experiment as well as observation in the study of Nature.

The production of plants from seed, and the manifold changes which take place during growth and decay, have

been subjects of great interest to thoughtful men from the earliest times ; but with chemistry in its infancy, there was little likelihood of any attempt at an explanation of such phenomena being more than mere conjecture, and as a consequence the whole matter remained incomprehensible for many years.

Food of plants. The earliest beginnings of an intelligent explanation of such phenomena may be said to date from



FIG. 1.—Bernard Palissy.

the times of **Bernard Palissy**, a Frenchman, who was born in 1510 of humble parentage, and, destitute of higher education, began life as a common potter. Later he became the greatest authority on the subject. His work was not confined to the potter's art, as he was the first investigator to direct attention to the necessity of mineral matter for

the growth of plants, and also to the return of the said mineral matter to the soil, when crops either underwent natural decay, or were burnt. That plants require for their full development something more than mineral salts escaped attention, no doubt owing to the fact that the composition of the atmosphere was then unknown.

From that time until the early seventeenth century, investigations appear to have been designed mainly for the purpose of discovering the fundamental principles of

vegetation—that is, the substance or substances present in soils directly responsible for the production of vegetable matter. How far that end was accomplished may be judged by the conclusions attained, which were to the effect that fire, air, earth, and water all contributed, though to what extent was not definitely ascertained.

Respiration. **Van Helmont's** enquiries, in the early seventeenth century, into the nature of carbon dioxide (then known as gas sylvestre), and the discovery of oxygen by **Priestley** in 1774, paved the way for a fuller understanding of the important phenomena relative to the life of plants; but it was not until the classical researches of **Th. de Saussure** had been published in 1804 that any real advance was made. To him is due the honour of having first seriously undertaken investigations for the purpose of elucidating problems relating to how plants grow and how they feed. His conclusions that plants absorb oxygen and evolve carbon dioxide, that is, respire; that green plants under the influence of light absorb carbon dioxide and liberate oxygen, retaining the carbon for the manufacture of organic compounds; and that nitrogen although absorbed in small quantities from the soil, is essential for plant growth, are as true to-day as they were a hundred years ago.

The conclusions of de Saussure were not, however, accepted by his contemporaries, and notably not by **Sir Humphry Davy**. Davy's lectures for the Board of Agriculture in 1803, and the issue of his book *Elements of Agricultural Chemistry* ten years later, entitled him to acknowledgment as an authority on the subject. Yet upon one important point these investigators did not agree; for while de Saussure concluded that plants obtained most of their carbon dioxide from the air, Davy believed that a large portion was absorbed by the roots from the organic matter, that is the **humus**, of the soil.

Field experiments. About the year 1833, **Boussingault** commenced his celebrated field experiments on his own farm in Alsace. Previous to his work most of the experimental work had been conducted in laboratories on a very small



FIG. 2.—Baron Liebig.

scale, and as a consequence the results were accepted with some caution by practical men. The definite results Boussingault obtained in the field on the manuring of crops and on the effect of including leguminous crops in any rotation, thereby increasing the store of nitrogen in the soil (due to the accumulation of nitrogen in the roots of the legumes), decided once

and for all that the intelligent application of knowledge secured in the laboratory may often be transferred to the field, without in any way affecting the conclusions drawn therefrom. These experiments were in reality the beginning of field demonstrations, a method of experimenting which has done so much towards solving many important problems connected with manuring and crop production.

The mineral theory. It was, however, left to **Justus von Liebig**, Professor of Chemistry at Giessen (1824-52), to lay the foundation of what may be called a rational system of agriculture.

In presenting by request a report upon 'Organic Chemistry in its application to Agriculture and Physiology'

to the British Association for the Advancement of Science in 1840, Liebig stated in his dedication, "A rational system of agriculture cannot be formed without the application of scientific principles, for such a system must be based on an exact acquaintance with the means of nutrition of vegetables, and the influence of soils, and actions of manures upon them."

Commencing with such firm convictions as to the value of chemistry applied to agricultural problems, one can scarcely wonder at the important results achieved by Liebig. He condemned the theory that humus was the source from which growing plants directly obtained their organic food ; but he firmly held and adhered to the opinion backed by his own experiments, that the carbon was derived from the carbon dioxide in the atmosphere. He also propounded his mineral theory, which was to the effect that potash and phosphates are essential elements for plant growth ; and that they could be supplied artificially by mineral salts. He, however, omitted to include the element nitrogen, and this to some extent militated against the value of his otherwise distinguished researches.



FIG. 3.—Sir J. B. Lawes.

The nitrogen problem. Liebig knew that nitrogen was essential for the full development of crops ; but he was mistaken in supposing that plants obtained this element through their

leaves from the ammonia in the air. His great opponent at this time was **John B. Lawes** (Fig. 3), founder of the Rothamsted Experimental Station at Harpenden, Herts. While Lawes was in agreement with Liebig on some points, he objected to Liebig's conclusions on others, the chief of which were :

1. That crops increase in proportion to the potash and phosphates supplied.
2. That nitrogen is obtained from the ammonia present in the air.

To investigate Liebig's deductions, Lawes had carried out many well-devised experiments, and continued to do so, thus founding the celebrated experimental station at Rothamsted, where to this day important investigations of an agricultural nature are in progress.

Such, then, put very briefly, are the main features pertaining to the commencement and progress of agricultural chemistry. In the next chapter present-day ideas with regard to how plants feed, and how they grow, will be considered.

CHAPTER III.

HOW PLANTS FEED AND GROW.

PRACTICAL WORK.

[For the methods of applying the tests referred to in the following experiments, the student should refer to pp. 7 to 19.]

1. TAKE portions of any plant and heat them in a porcelain dish over a bunsen burner. Charring takes place and water is driven off, thus indicating that plants contain carbon and water.

2. Obtain portions of vegetable matter and place them in a test-tube. Add a little soda-lime and heat the mixture gently. Test the escaping gas with litmus paper. Is ammonia present? Is nitrogen present? Do plants contain nitrogen?

3. Ignite a handful of finely chopped grass until ash only remains. Dissolve the ash in dilute hydrochloric acid, and test for the following metals: iron, calcium, magnesium, sodium, and potassium. Test also for phosphoric acid.

4. Dig up and examine any flowering plant, noting particularly the important morphological differences between root, stem, leaf, and flower. Describe the differences observed.

5. Sow mustard seed in very fine sandy soil. When 4 to 6 green leaves have been formed, dig up the seed and carefully wash off the adherent soil. Notice the very fine root-hairs. What are their functions?

6. Obtain sections of a young ash stem, a bean stalk, and of wheat straw. Examine the sections microscopically and notice the difference in appearance. Identify the epidermis, cortex, vascular bundles, cambium, bast, wood and pith (where present) by the aid of Fig. 6.

7. Obtain sections of a leaf and examine them microscopically. Identify by the aid of Fig. 16, the epidermis, with stomata, the palisade layer with chlorophyll grains,

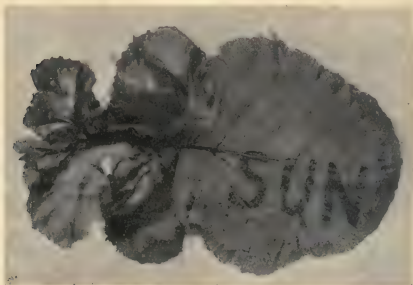


FIG. 4.—Starch print on a leaf.

and the peculiar spongy tissue through which runs the vascular bundles. Note also the peculiar shape of the vascular bundles.

8. Cover a leaf with brown paper in which has been cut the word "Sun." At noon on a bright day remove the leaf and place in boiling water for half a minute, then soak it in warm alcohol until pale in colour. The alcohol extracts the chlorophyll. Note the colour. Now place the leaf in a flat dish containing iodine solution. The word "Sun" is plainly seen on the leaf (Fig. 4). Explain why.

9. Enclose a small branch of any growing plant or tree in a flask the neck of which is closed by a loose cork. Water collects in the flask. How did it get there?

10. Fill a filter funnel with several small plants such as mustard and cress, or young lettuce plants, or better still

water weeds. Invert the funnel in a beaker containing water. Invert over the delivery tube of the funnel a test-tube filled with water, as shown in Fig. 18. Stand the apparatus in direct sunlight. Does gas collect in the test-tube? If so, test it, name it, and explain how it got there.

II. Examine the sawn end of a felled tree. Note the natural concentric rings or lines upon it. On examination with a pocket lens the rings are seen to be composed of compact wood (autumn wood) with softer rings of spring wood between the compact layers. Why is autumn wood more compact than spring wood?

The growth of plants. The germination of seeds, the growth of root, stem, leaf, flower, and finally mature seed of the same nature as those originally sown, are familiar to everyone; but the question, How do plants feed and grow? can only be answered by a more detailed examination of their structure, functions, and products than suffices for the acquisition of the above knowledge, which could be obtained by a very casual observation of germinating seeds and living plants. In order to understand how plants feed and grow, it is necessary first to know something of their structure.

The structure of plants. The study of the external parts of plants, such as stem, root, and leaf, is known as **Morphology**. A more detailed knowledge externally and internally is included under the term **Anatomy**; while minute anatomy, or microscopic anatomy, is known as **Histology**.

An examination of any ordinary flowering plant at once reveals the presence of root, stem, and leaf, with some leaves modified for reproductive purposes, known as flowers (Fig. 5).

The **root** is generally that part of a plant which enters the soil. Its chief functions are (1) to absorb mineral

food, (2) to act as a support or foundation for the whole plant. Aerial roots and roots of many water plants do

not enter the soil, but these are not of importance agriculturally.

The **stem** is that portion of a plant which tends to grow upwards towards the light, and acts as a conduit between the root and leaf.

A **leaf** is a flattened expansion which differs from the stem both in structure and function. Leaves are organs of absorption, respiration, and excretion.

A **flower** is made up of leaves modified to serve for reproductive purposes.

When a portion of any root, stem, or leaf is cut into very thin slices (sections) and examined under a microscope, it is seen to be composed of cells. Each cell is surrounded by a cell wall,

which consists of material (**cellulose**) denser than the cell contents, and as a consequence more easily seen. Unless special care is exercised the cells may be thought to be empty. Close examination will, however, reveal the presence in the cells of a clear gelatinous substance known as **protoplasm**. Protoplasm is a very complex nitrogenous compound, and is really the living part of the plant. If a section is stained by an aniline dye, the walls and contents will be more readily seen. The cells are not all



FIG. 5.—Complete plant.

alike; some are more or less spherical, with spaces between (intercellular spaces); others appear as a perfect mosaic, with very thick walls and no spaces; while a third group are large circular, thick-walled cells devoid of protoplasm.

These three distinct kinds of cells are known respectively as **parenchyma**, **fibres**, and **vessels** (see *m*, *l*, *r*, in Fig. 7).

Each variety has special work to perform. Whenever a group of cells has a common origin and a common function, that group is known collectively as a **tissue**. Thus we have parenchymatous tissue (soft living tissue), fibrous tissue (thick-walled for strengthening the plant), and vascular tissue (vessels for conveying solutions).

Whether stem, root, or leaf is examined, these three tissues are always present. They are not, however, always in the same relative position with regard to each other; and it is by a comparison of their arrangement in any section that it is possible to state whether any section is from a root, stem, or leaf.

The cell and cell wall. The cell wall consists of a substance known as cellulose, which has the composition $C_6H_{10}O_5$. Cotton wool, blotting-paper, and filter paper are practically pure cellulose manufactured from plant cellulose.

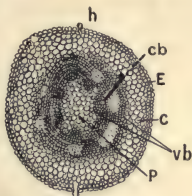


FIG. 6.—Cross section of stem.

- E. Epidermis.
- C. Cortex (parenchyma).
- vb. Vascular bundles.
- P. Pith.
- cb. Cambium.

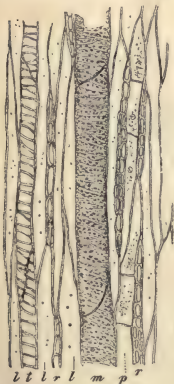


FIG. 7.—Longitudinal section of stem.

- m*. Vessels.
- l*. Fibres.
- r*. Parenchyma.

Cell contents. The contents of a young growing cell consist largely of protoplasm, but other substances, starch,

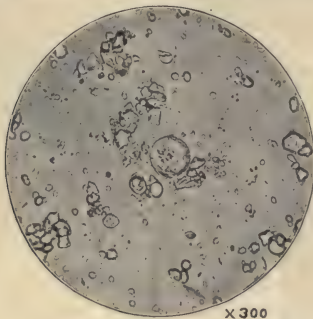


FIG. 8.—Starch grains in oats.

Photo. by J. E. Barnard.

cell sap, proteid grains, oil and mineral matter, are also present. When careful microscopical examinations are

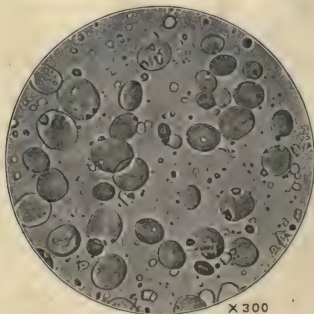


FIG. 9.—Starch grains in barley.

Photo. by J. E. Barnard.

made of sections of potato, or of seeds of wheat or oats, small grains of starch are noticed (Figs. 8 to 13). Each

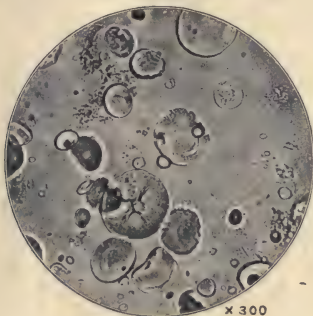


FIG. 10.—Starch grains in rye.

Photo. by J. E. Barnard.

starch-producing plant has characteristic starch grains, and by means of these it is possible to determine by the

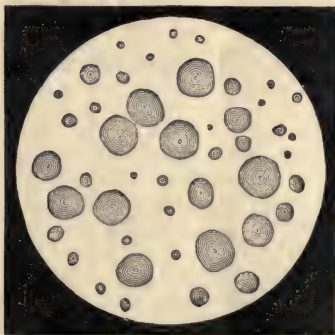


FIG. 11.—Grains of wheat starch. Highly magnified.

microscope what plants are under examination. In fact, by examination of the starch grains one is able to detect adulterants in such substances as flour and various meals, such as oat meal and barley meal.

Cell sap. The watery fluid (found in cells), which contains many substances in solution, is known as cell sap. The important compounds found in sap are sugar and the soluble inorganic salts absorbed by the roots from the

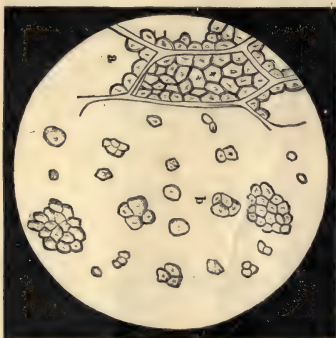


FIG. 12.—Grains of rice starch. Highly magnified.

soil. The chief sugars found in plants are *cane sugar* ($C_{12}H_{22}O_{11}$) and *grape sugar* ($C_6H_{12}O_6$). Sugar being soluble is found in solution in the sap. The inorganic salts include among others compounds of potash.

Proteid grains. These are found in the cells and are sometimes known as *aleurone* grains. They contain a high proportion of nitrogen.

Fats and oils. These are generally found in the cells of seeds. As examples, linseed oil and cotton-seed oil may be mentioned. They are extracted from linseed and

cotton-seed by pressure, the residues after extraction being known respectively as linseed and cotton cake.

Mineral crystals. Crystals of insoluble inorganic salts are sometimes found in cells, the chief being calcium oxalate (CaC_2O_4) and calcium carbonate (CaCO_3).

How cells behave under certain conditions. As cells contain a living substance, protoplasm, they respond to external stimuli just as living plants and animals do.



FIG. 13.—A thin slice of potato. Highly magnified.
a. Cell walls composed of cellulose. b. Starch grains.

Many of the lower plants consist of one cell only, and by careful study of these we are able to gain very accurate knowledge as to the effect of external conditions on cells. It has been found that just as mature animals and plants require certain conditions to be satisfied if vital activity is to continue, so each cell demands the same conditions. The important conditions are air, moisture, a suitable temperature, and of course sufficient food. In these circumstances each cell can carry out its proper functions, thus becoming an important contributor to the vital activity of the whole plant.

How cells absorb food material In order to understand how cells absorb nutrient solutions from the soil, it is best to prepare an artificial cell and study the effect of solutions upon it. If the mouth of a thistle funnel is

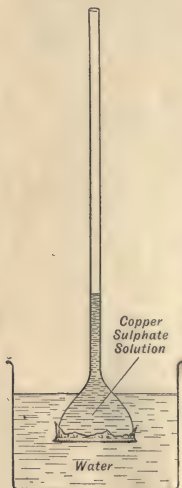


FIG. 14.—An artificial cell.

covered with a piece of pig's bladder or parchment, as shown in Fig. 14, and the funnel and part of the stem filled with a strong solution of some coloured salt, such as copper sulphate or permanganate of potash, to represent the cell sap, we have an artificial cell. It will be noticed that when the funnel is immersed in tap water the coloured liquid rises in the stem; but if immersed in very strong salt solution the liquid falls in the stem. That is, the tap water passes through the bladder or parchment into the cell quicker than the coloured solution passes out, but when immersed in strong salt solution, the coloured solution passes out through the membrane quicker than the salt solution passes in. This is exactly what takes place when cells are exposed to weak and strong solutions respectively.

The diffusion of solutions through animal or vegetable membranes is known as **Osmosis**, or osmotic action. It is affected by temperature, as well as by the strength of the solution.

If two thin slices of beet-root are placed successively under a microscope, the cells and coloured contents are clearly seen. If to one slice a drop of distilled water is added, the cells swell up or become turgid. If to the

second a drop or two of strong salt solution is added, the cell contents contract. A very weak solution like distilled water diffuses into the cell more quickly than the cell sap diffuses out, while the reverse is the case with the strong salt solution. This is exactly what happens in the roots of growing plants. The cells of the root in contact with the soil grains (which in fertile soils are always moist) absorb the weak soil solution. If, due to any circumstances, the soil solution becomes the more concentrated, then plants lose instead of gain by diffusion, the plant in fact droops or wilts. Under such a condition the plant is said to be **plasmolysed**, and the phenomenon is known as **plasmolysis**.

The portion of the root which absorbs soil solutions. When any small plant is very carefully dug up and the soil washed away by a fine stream of water, the tips of the finest root can be seen

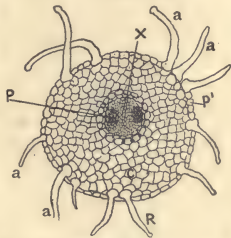


FIG. 15.—Section of root showing root-hairs, *a, a*.

to be covered with delicate fibres or hairs. If examined microscopically, they prove to be elongated cells and not true hairs (Fig. 15). These are the cells through which most of the soil solution enters the plant. After absorption the solution then passes to the layer immediately below the surface cells of the root (that is, the **cortex**), and finally into the wood vessels, which act as distributing channels.

The stem. The internal structure of the stem differs from that of the root, but the tissues present are very similar. An examination of Fig. 6 shows that epidermis, cortex, cambium, bast vessels, and wood vessels are

present. The wood vessels have the same function as those of the root; in fact, they continue the distribution of the soil solution through the plant. The stem thus acts as a connecting link between the root and leaf.

The leaf and its functions. A leaf is a flattened expansion which differs from the stem on which it is borne. It has for its object the absorption of gases from the air, the elimination of waste water, and the manufacture of



FIG. 16.

P=palisade layer.
Sp=Spongy parenchyma.
S=Stomata.
VB=Vascular bundles.

carbon compounds, such as starch and sugar. Careful examination of the leaves shows that they are well suited for this purpose. There is a large extent of surface exposed to the air, and the leaves are delicately joined to the stem or branches by the leaf stalk, thus allowing free movement in the slightest breeze, such movements increasing evaporation and facilitating the supply of fresh air.

Structure of leaves. The internal structure of a leaf

differs greatly from that of the stem on which it is borne, yet such tissue systems as are found in roots and stems are present. One notable difference is seen in certain cells of the epidermis and cortex, or, as it is here called, **spongy parenchyma**. The cells known as **stomata** (Fig. 17) serve as a means of interchange of gases between the air and the plant. The cells on each side of the stomata, known as **guard cells**, are so arranged that they act as regulators. During dry weather, when little water is absorbed, they are practically closed, while in wet weather they are wide open:

Stomata are found chiefly on leaves, but other parts of plants may possess them. Horizontal leaves have most

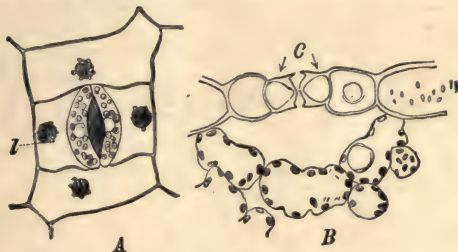


FIG. 17.—Stomata.

A, Surface view. *B*, Cross section. *C*, Guard cells.

on their under surface, vertical leaves on both sides, while floating leaves generally have them on the upper surfaces only.

The green colouring matter of leaves. The green colouring matter of leaves is known as **chlorophyll**. It is found in the cells of the green parts of plants in small grains, known as chloroplasts, present chiefly in the **palisade layer** (Fig. 16). The grains are easily seen on microscopic examination. Chlorophyll grains in sunlight are able to



FIG. 18.—Oxygen is given off from fresh green plants in sunshine, and can be collected as shown.

decompose the carbon dioxide of the air, liberating the oxygen and retaining the carbon. The ultimate result of this change, which at present is imperfectly understood,

is that sugar and then starch are produced in the leaf. That such is the case can be proved by exposing half a growing leaf to direct sunlight, while shading the other half. On testing the leaf for starch it will be found that the exposed half contains many starch grains, while the shaded half does not. Only green plants carry on this manufacture.

Plants devoid of green colouring matter obtain their carbon from some green plant, or directly from decomposed vegetable matter. Many fungi, causing diseases of plants, live at the expense of carbon compounds manufactured by their green host plant, while mushrooms live on dead organic, that is, carbonaceous matter.

The whole process in a green plant, from the absorption of carbon dioxide to the manufacture of starch, is known as **carbon assimilation** or **Photosynthesis**.

Growth of a plant. When a chemical analysis is made of any of our ordinary farm crops, the following elements are recognized: carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, calcium, potassium, sodium, iron, silicon, magnesium, and chlorine. It has been proved experimentally that the elements necessary for healthy growth are: carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, magnesium, and calcium. The first-named element enters the plant as carbon dioxide by way of the leaves, together with some hydrogen and oxygen also, as water. The greater portion of the water, however, enters through the roots, taking with it in solution the remaining elements, not, however, as elements, but as compounds. For example, the nitrogen enters chiefly as nitrates, sulphur as sulphates, phosphorus as phosphates. As previously mentioned, this mineral solution is very weak; therefore excess of water is necessarily absorbed, the excess being eliminated chiefly through the stomata of the leaves.

The whole phenomenon of absorption and elimination of surplus water is known as **transpiration**, and was first proved by Stephen Hales as early as 1727 (Fig. 19). The current of water which is continually rising in the plant carries with it the compounds of nitrogen obtained from the soil, and finally arrives in the leaves. Here they meet the carbon compounds, the result being the production of those highly complex nitrogenous compounds known as

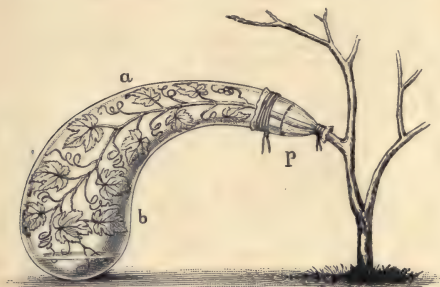


FIG. 19.

a. Glass retort.

b. Bough of vine placed in retort.

p. Piece of bladder forming air-tight joint between retort and branch.

Stephen Hales's experiment.

proteids, or albuminoids. It should be particularly noted that only plants can manufacture proteids; animals are unable to do so. The elaborated products are then conveyed to the various parts of the plant chiefly by means of the bast vessels, or **sieve tubes** (Fig. 7), and are ultimately built up into the structure of the plant.

Growth in length and thickness. When a broad bean is kept moist and warm for some days, a root soon makes its appearance, increasing in length rapidly. If the growing root is marked off in millimetres with Indian ink,

it will be noticed that as growth proceeds the distance between the marks increases just behind the tip of the root. It is here that increase in length, that is, growth in length, takes place. The same happens at the tip or the top of the stems of trees and other plants. At the very tip the cells divide, but do not increase in length.

When a cross-section like that shown in Fig. 6 is examined, a layer of cells known as the **cambium** will be noticed. The cambium is the layer which by division increases the thickness of the stem. On the outside of the cambium is the **bast**, composed of bast vessels—which are the conduits for conveying the material manufactured in the leaf fibres for strengthening purposes—and softer parenchymatous tissue. Inside the cambium is the wood—consisting of wood vessels used for transference of water from the root to the leaf fibres for strengthening—and soft parenchymatous tissue. The wood and bast are known as **vascular tissue**, as they are made up chiefly of vessels. When wood and bast (with intervening cambium) are present in patches (noticeable in cross-section), they are known as **vascular bundles**, that is, bundles of vessels. The intervening layer, or layers, of cells separating vascular bundles are called **medullary rays**, as they spring from the medulla (or pith or central collection of cells) in a ray-like manner. The pith consists of dead cells.

Outside the bast are cortex cells; and external to the cortex is the epidermis, or external layer.

As growth in thickness proceeds, the cells external to the cambium must be under great pressure, as the cells external to the bast do not multiply, and as a consequence these external cells often crack and scale off. The pressure towards the centre is always great, especially in autumn, due to growth in thickness taking place quicker than the expansion of the outer cells. Autumn wood is consequently more compact than spring wood. During

winter the outer cells expand or scale off, thus the pressure is relieved. Spring wood when produced is under less pressure, and is therefore softer and more spongy.

The source of energy required to build plants. In order that the complex compounds produced in the leaves may enter into the structure of plants, expenditure of energy is required to carry out this construction. This energy is obtained by breaking down the elaborated products into simpler compounds. When complex compounds are reduced to simpler compounds, energy is liberated; thus in every plant a building up or **anabolic** process proceeds in the leaves, under the influence of sunlight, and green colouring matter; and a breaking down or **katabolic** process in other parts of the plant. The important substances produced by anabolic processes are those of the nature of protoplasm; while good examples of katabolic products are the cell wall (cellulose), nitrogenous substances of less complexity than protoplasm known as amides, also oils, fats, and various excretions, such as resins and essential oils.

QUESTIONS.

1. What are the following: cell, cell wall, protoplasm, and cell sap?
2. What are the functions of the stem, root, and leaf of a plant?
3. How do plants absorb their mineral food?
4. What are the important elements necessary for plant growth, where are they found, and how do they enter the plant?
5. Write a short essay on carbon assimilation or photosynthesis.
6. Make a sketch of a cross-section of any plant, showing the position of pith, vascular bundles (wood and bast), cortex, and epidermis.

7. Sketch a cross-section of a leaf, showing epidermis, palisade layer, chlorophyll grains, vascular bundles, spongy parenchyma, and stomata.

8. Describe the action of the stomata.

9. What is transpiration, and what use is it ?

10. How do plants increase in length and thickness ?

11. From what source is the energy derived which is expended on the growth of plants ?

12. What is osmosis ?

13. All plants respire, but only green plants assimilate carbon from the air. Explain this clearly.

14. Explain fully how starch is made in the plant. How would you test for starch in the leaf ? What use is starch to the plant ?

15. What are the effects upon plants of a great excess of soluble salts ? How are these effects brought about ?

CHAPTER IV.

SOILS.

PRACTICAL WORK.

1. EXAMINE any quarry or cliff. Note the surface soil, the hard rock below, and the intermediate stratum partially disintegrated. Endeavour to explain the transition from hard rock to surface soil.

2. Obtain specimens of sandstone and limestone. Grind each to a coarse powder. Add a little vegetable matter, such as leaf mould, to each. Do these mixtures resemble soil? Could they be used as soil? Try if plants will grow in them.

3. Collect samples of clay soil, sandy soil, loam and chalk soil. Describe the colour and texture (if coarse or fine).

4. Fill two lamp glasses, one with sand and the other with clay. Tie linen over both ends of the glasses. Weigh the glasses carefully. Immerse the glasses in water and allow them to drain for five minutes. Weigh the glasses again. Ascertain which soils hold most water. Experiment with other soils, and arrange them in the order of their **water-holding power**.

5. Obtain several boxes of one cubic foot capacity. Weigh the boxes; then fill them with different kinds of soil and weigh again. Compare the weights of the soils, with the ease or difficulty in cultivating the said soils. Are the heavier soils the easier to cultivate or not?

6. Spread a layer of soot on some garden loam. On another patch spread a layer of chalk. Place thermometers in the soot, chalk, and untouched soil, and note the temperatures at fixed hours during the day. What do you conclude as to the effect of the colour of a soil upon its temperature? After sunset, observe the temperatures again. Which soil cools quicker?

7. Take the temperatures of drained and undrained soils at fixed hours. Which is the cooler, and why?

8. On a wet day cut slits in various soils with a pocket knife. Place strips of blue litmus paper in the slits. Examine the paper after twenty-four hours. What do your observations show?

9. Obtain about five grams of sand, clay, and loam; place them in separate beakers. Add about 200 c.c. of distilled water and stir well. Allow the mixture to settle, then filter, using a filter paper the dry weight of which you know. Collect the filtrate in each case. Wash the residue on the filter paper with distilled water, first making sure you have left none of the earth in the beaker. After completion of the washing, dry the undissolved portion of the soil and weigh. The remainder is in the filtrate. If you carefully evaporate the filtrate to dryness, you will obtain the soluble matter present in the five grams of soil. This, plus the insoluble matter on the filter paper, should equal five grams. Unless you have carried out the experiment very carefully there will be some difference, due to loss.

10. Treat another five grams in a similar way, but instead of evaporating the filtrate to dryness, test the solution for nitrogen, phosphoric acid, and potash as follows:

Nitrogen. Divide the water solution into three parts. Place one part in a round-bottom flask, and add 10 c.c. of concentrated sulphuric acid and half a gram of salicylic acid; heat the solution in a slanting position in the draught chamber for half an hour; then let it cool. Dilute with distilled water; add caustic soda till alkaline and

warm gently. Test for ammonia by holding a piece of litmus paper in the neck of the flask. If ammonia be detected, nitrogen in one form or another must have been present in the soil.

Phosphoric acid. Evaporate the second part to dryness, ignite, dissolve in HCl, filter and evaporate again. Add nitric acid until decidedly acid, warm the solution and filter. Add two cubic centimetres of a solution of ammonia molybdate. A yellow precipitate indicates phosphoric acid.

Potash. Evaporate the third part to dryness in a basin. Ignite the residue gently and add 20 c.c. of dilute hydrochloric acid. Filter the mixture, evaporate the filtrate to dryness, and again add very dilute HCl (0.5 per cent.). Add 2 c.c. of platinum chloride solution and evaporate very slowly until just pasty. Then add 10 c.c. alcohol and filter. If an orange-coloured crystalline precipitate, which will dissolve in hot water, is left on the paper, potash was present in the solution.

These experiments should be carried out in detail in order to prove that the three above-named important constituents are actually present in soils.

11. Observe the temperatures of soils which have been mulched—that is the surface of which has been lightly hoed—and those which have not been mulched. Estimate the moisture in, say, ten pounds of soil taken from mulched and unmulched plots. This can easily be done by taking the samples quickly, weighing at once, and then spreading them out on a tray. Expose the samples to the air for a week; then weigh again. Continue weighing each day until there is practically no further loss. Calculate the percentage of moisture lost. Which soils contained most moisture, the mulched or the unmulched?

12. Obtain about 20 grams of clay; place it in a beaker; add water until the beaker is nearly full. Stir the mixture well, and set it aside for twenty-four hours.

Treat a second 20 grams as above; but after adding the water, add also a little lime. Stir the mixture well, and set it aside for twenty-four hours.

After allowing the mixtures to settle as above mentioned, examine the two solutions. That which had lime added will have cleared better than that to which no lime was added, and the sediment from the lime will be more of a flaky nature. This is exactly what happens when lime is added to sticky clay soils.

Soils. Agricultural chemistry is the chemistry of substances of an agricultural nature. The word agriculture means to work, till, or cultivate land, or soil. Land is worked, tilled, or cultivated for the purpose of rendering it fit to produce crops. Uncultivated land will produce a crop, but by experience the farmer has learned that heavier crops can be grown on cultivated soils than on those uncultivated. The object of cultivation is therefore crop production, and the foundation of agriculture is the soil.

By the term **soil**, the farmer understands "That part of the earth which is cultivated and in which the roots of plants spread for support and for the purpose of obtaining their mineral food." Mineral food is not the only food the plant absorbs. In addition, green plants take food from the air in the form of carbonic acid gas (carbon dioxide, CO_2). From the earth and the air, plants are able to build up the whole of their structures. If, however, either is absent, they are unable to do so.

A soil may be considered from two points of view, namely: 1. What it is; 2. To what use it is put. If we study the first of these aspects we are dealing with the physical and chemical properties of a soil, while in the second we are considering how the farmer employs the soil in order to aid him in crop production. The first may be classed as **Soil Physics** and **Soil Chemistry**, the second as **Soil Economics**.

How soils are formed. The hardest rocks found in nature will, if exposed to air, rain, and frost, crumble

gradually and will ultimately form a fine powder. The action of these agents upon rocks is known as **weathering**. Soils are therefore produced by the weathering of rocks. An examination of any quarry will show that just at the surface of the solid rock there is evidence of crumbling; that is, the rock is slightly broken up or shattered. Above



FIG. 20.—Natural section of quarry.

Showing (a) surface soil; (b) intermediate layer undergoing weathering; and (c) hard rock.

this solid rock finer material is found, and this is surmounted by still finer soil or earth, on the actual surface of the ground (Fig. 20).

The soil thus produced above the rock may remain in this position, or it may be carried by water or wind to some other place. If it remains where produced we get a **sedentary** soil; if carried away and deposited elsewhere, it forms a **transported** soil. The composition of a sedentary soil depends therefore upon that of the underlying rock; while a transported soil may be an intimate mixture from several rocks.

We will first deal with soils from the point of view of what they consist; then with the properties of the individual constituents, and later with soils as a whole.

The composition of soils. Examination of any soil with a pocket lens will show that it consists in a great measure of particles of mineral matter; some small, others large; some **crystalline**, that is, with natural geometrical shape; others **amorphous**, that is, without definite shape. Unmistakable evidence of a vegetable nature may also be found; in fact, small portions of plants may be identified.

With no further aid than a pocket lens, it may be concluded that soils consist entirely of dead matter, but this is far from the truth. When a small portion of soil is examined with a microscope, which magnifies many more times than a pocket lens, numerous small organisms known as **bacteria** are found. It is these which bring about many of the most complicated changes in soils. Instead of consisting entirely of dead matter, soils teem with minute forms of life; and if we removed entirely the living organisms from them few chemical changes could take place.

Important substances found in soils. The terms sand, clay, loam, and chalk are commonly used by farmers in describing soils. It is therefore advisable to know something about these substances.

Sand. Pure sand consists chemically of dioxide of silicon (SiO_2). As found in soils it is never pure, the chief impurity being oxide of iron. The reddish colour of sand and sandstone is usually due to this impurity, although other coloured substances may give to sand a distinctive shade.

Clay. Pure clay is known as kaolin, or China clay, and is quite white. It is rather complex in composition, the chemical formula for pure clay being $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. It is therefore hydrated silicate of alumina.

Clay as found in soils usually is not white ; its colour may vary from white to nearly black, due chiefly to the presence of oxides and sulphides of iron and decayed vegetable matter. The impurities present in clay are numerous, and these impurities are actually of much more value to the farmer than the clay itself. Some of the impurities in clay are used as food by plants ; clay itself never is. A similar statement is true of sand.

Loam. This word is used by farmers to indicate a mixture of sand, clay, and vegetable matter. When vegetable matter has so far decayed as to render it impossible to state from what source it has been derived, it is called **humus**. Humus is present in loam to a greater extent than in either sand or clay. It is the presence of humus which gives to the mixture its loamy characteristics.

Humus is an extremely important constituent of soils. It contains much of the carbon, hydrogen, and oxygen present in the original vegetable matter from which it was produced, and practically all the nitrogen and mineral matter. It therefore returns to the soil the constituents which the vegetable matter originally took away. The nitrogen present in humus, after undergoing suitable change, is absorbed by plants ; it becomes, in fact, a food for plants.

As stated already, soils contain useful bacteria. These organisms require food to live ; humus supplies it. Again, humus holds together the particles of sand, and makes clay less plastic or sticky. Humus is therefore a very important constituent of soils ; for it supplies nitrogenous food for crops and organic food for bacteria, as well as binds sand and opens out clay.

Carbonate of lime. This constituent of soils is known to the farmer as chalk and limestone ; chemically it is carbonate of lime, or calcium carbonate, and its formula is CaCO_3 . It is present in all fertile soils, and its absence

causes soils to be acid. Acid soils are unfitted for the growth of cultivated crops, and useful bacteria do not flourish unless the soil is neutral or slightly alkaline. Carbonate of lime is present in very variable amount; some soils contain less than 1 per cent., while others of a chalky nature contain more than 50 per cent. If carbonate of lime be present in sufficient quantity, a soil cannot be acid; and if deficient it is usually applied by farmers in the form of lime (which becomes converted into the carbonate by exposure to the air) or chalk.

Kinds of soils. It has been stated already that soils are called by different names according to their constitution. If a soil consists chiefly of sand it is called a **sandy soil**; if of clay, a **clay soil**; if a mixture of the two, plus some vegetable matter, it is known as a **loam**. It should, however, be noted carefully that a sandy soil may and generally does contain some clay, and a clay soil some sand. Also, most soils contain decayed or decaying vegetable matter. The more open the soil, the less decayed matter does it contain, because an open soil allows of free admission of air, which brings about oxidation of the vegetable matter. In clay soils air is not admitted so freely, therefore the organic matter is preserved.

We may classify soils in several ways thus:

According to weight. 1. Heavy (Sandy soils).
 2. Light (Clay soils).

According to working. 1. Heavy to work (Clay).
 2. Easy to work (Sand).

According to composition; that is, as regards clay, sand, etc., present.

1. **Sandy soil**, containing not more than 10 per cent. of clay.
2. **Clay soil**, containing not more than 10 per cent. sand.
3. **Loam**, which is a mixture of sand and clay, with vegetable matter.

4. **Marl** is clay mixed with limestone or chalk. Intermediate qualities are also known as sandy loam and clay loam. These names have not a very definite meaning.

According to condition. Dry, wet, rich, poor, shallow, fine, coarse; these all refer to certain distinctive properties sufficiently explained by the words used.

According to reaction with manures. *Hungry* soils often require manuring. *Grateful* soils respond well to manures. *Dead* or *deaf* soils do not respond to manures very well, if at all.

According to colour. Blue, red, brown, black, due to various impurities present, chiefly oxide of iron and organic matter.

It may be asked which soils are best? The answer to this cannot be given unless the kind of farming which is to be followed is known, for some crops do best on heavy clay land, while others are equally at home on light sands.

For general purposes a good average soil will contain sand, 50 to 70 per cent.; clay, 20 to 30 per cent.; carbonate of lime, 8 to 10 per cent.; organic matter (humus), 8 to 10 per cent.

Physical properties of soils. The important physical properties of soils are: 1. texture, 2. colour, 3. specific heat, 4. water-holding power, 5. weight, 6. temperature.

Texture. By the texture of a soil is meant its physical structure, or the sizes of its particles and their arrangement. Generally, it may be taken that a soil with large grains is of coarse texture, while when the grains are very small its texture is fine. But texture is not entirely a question of the size of the particles. The presence of certain salts causes the formation of compound grains, or crumbs, or kernels, and these to some extent determine the texture. But from our point of view, it will be sufficient at present to consider texture as dependent upon the fineness or coarseness of the particles, as the case may be. A soil

which has coarse texture is easier to plough than one which is very fine. For example, a clay soil consists of particles of which about 50 per cent. are so small that it takes 25,000 to measure one inch if placed side by side; while in a sandy soil only about 5 per cent. of its weight consists of particles as small as these.

The coarseness or fineness when taken in conjunction with the packing of the particles determines what space there is between the particles; that is, the **pore space**. This space varies from about 25 per cent. in coarse sands to about 50 per cent. in fine clays. Upon the pore space depends the amount of water the soil can actually hold if saturated. Thus, in the above case, a sandy soil having 25 per cent. pore space, would be made up as follows: 75 per cent. soil and 25 per cent. filled either with air or water; while a clay soil would be composed of, say, 50 per cent. soil, and 50 per cent. of air or water or both.

Weight. Compared with an equal volume of water, some soils are nearly twice as heavy. The following results were obtained when one cubic foot of certain soils was weighed: sand, 110 lbs.; clay, 78 lbs.; loam, 90 lbs.; peat, 40 lbs. A cubic foot of water weighs 62 lbs.

Notice, that bulk for bulk, sandy soils are the heaviest. But although they are heaviest in weight, they are lightest or easiest to work or cultivate, while clay soils are lighter in weight but heavier to work. The reason why clay soils are lighter than sandy soils is that there is more air space, and less solid matter in clay soils than in sandy soils; therefore the weight is less.

Specific heat. The specific heat of a soil is the amount of heat required to raise the temperature of unit mass of that soil (say 1 lb.) one degree Centigrade. The specific heats of different soils vary. Taking the specific heat of water as 1, the value for sand is about one-tenth; for clay, about one-fifth. The meaning of these values is (taking

the number for sand as an example) that the heat which would raise the temperature of one lb. of water 1 degree Centigrade would raise that of one lb. of sand 10 degrees, because the specific heat of sand is one-tenth that of water. The importance of this will at once be apparent; for if the sun's rays can raise the temperature of a certain amount of water one degree Centigrade, the same heat would raise the temperature of an equal quantity of sand 10 degrees. It follows, therefore, that the lower the specific heat, the quicker the soil becomes heated. Remember that we are considering the specific heat separately. Under field conditions there would be other circumstances affecting the temperature, some of which might tend to lower it instead of raising it; of these the most important is the water-holding power.

Water-holding power of soils. If a sandy field be examined twenty-four hours after a heavy rain, and a clay

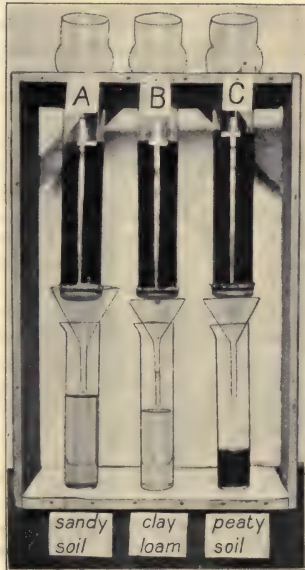


FIG. 21.—Water-holding power.

A, B and C have each had the same volume of water poured on them. A retains the least and C the most, while B is intermediate.

field at the same time, it will be invariably found that the sandy soil allows water to drain away better than the clay soils ; that is, the water-holding power is lower. This has a very important bearing upon the temperatures of soils, as will be shown later (Fig. 21).

Colour. Soils vary greatly in colour. Some are white (chalk), others grey (chalk marl), others nearly black (marsh land), while clay may be practically any colour from white to brownish black. Pure clay and pure sand are quite white. The impurities present give to these soils their colour. The most important colouring substances in soils are compounds of iron. Iron is a white metal, but when combined with oxygen (oxidised) and water, it varies in colour from greenish white, through yellow, red and brown to nearly black.

Organic matter also takes part to some extent in the colouring of soils. When vegetable matter decays, it becomes dark in colour, and to such decayed or decaying vegetable matter some soils owe their colour. However, irrespective of the actual colouring agent, we have to consider the effect of colour on soils. Suppose a layer of soot about half an inch deep to be spread on some garden loam, while on another patch chalk is spread to about the same thickness. If thermometers are placed in the soot, chalk, and the untouched soil, and the temperatures are taken at fixed hours during the day, the dark soil will be found to have become warmest. An examination later after sundown will show the soil which became warmest, cools quickest. From a simple experiment of this kind we can conclude that dark soils cause the temperature to rise during the day and to fall quickly in the evening. This effect of colour on soil temperatures is very important.

Temperature. The temperature of a soil varies greatly on account of the influence of internal and external conditions, the most important being : 1. composition,

2. water present, 3. inclination of the soil to the sun, 4. colour, 5. oxidation of organic matter.

The composition affects the temperature because different substances are affected by the rays of the sun to varying extents ; that is, their specific heats vary.

Water also affects the temperature in many ways. When warm rains reach the earth, heat is given up to the soil ; thus the temperature is raised from this source ; therefore, the soil gains heat. If water collects in the soil it displaces air ; and as water requires more heat to raise its temperature than an equal bulk of air, the tendency is for the water either to lower the temperature or to keep it low. If the soil is actually wet or becomes water-logged, it remains permanently cold. Soils which easily become water-logged are, therefore, apt to be cold.

Again, when water is evaporated, heat is absorbed. A soil which is wet is consequently cold for a second reason ; that is, the heat which would be used to raise its temperature (if dry) is expended in evaporating water. It follows that to get the maximum rise in temperature due to the sun's rays, a soil must not be water-logged. To prevent and remedy this, drainage is carried out. Not only does drainage remove superfluous water, but it also causes rain to sink, giving up its heat to the lower layers of soil, and causing air to follow and take its place. Efficient drainage consequently has a tendency to raise the temperature and does so to a very marked extent. Inefficient drainage or the absence of drainage results in a low temperature.

The position of a soil also affects its temperature. Consider, for example, a field inclined to the south. In the northern hemisphere it directly faces the sun during the hottest part of the day ; as a result its temperature is higher (other things being equal) than that of a field which faces north (Fig. 22).

As mentioned already, the colour of a soil has a very marked effect upon its temperature.

The decomposition of vegetable matter also produces a rise in temperature. If we collect a mass of vegetable matter, and leave it for some time, we find its temperature rises. This rise in temperature is chiefly due to oxidation of the vegetable, or organic, matter brought about not directly as when burned, but indirectly by the action of bacteria.

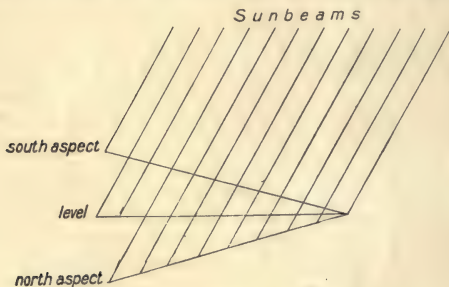


FIG. 22.

Exactly the same amount of heat is produced from the vegetable matter when it decays slowly, as is given off when it is burned directly. We may conclude, therefore, that soils gain heat: 1. from the sun, 2. by oxidation of vegetable matter, 3. from warm rains. Soils lose heat by radiation; that is, the escape of heat into the air, and also by the evaporation of water from their surfaces.

Importance of the temperature of a soil. Most cultivated plants require a temperature well above the freezing point, 32° F., for full development. In fact, if the temperature is much below 40° F., very little growth takes place. Seeds require for germination a temperature between 70° F. and 100° F. Some seeds will germinate

at lower temperatures than these, but generally, the temperatures given are those which produce the best results.

Soil bacteria also require a temperature well above the freezing point, if proper development is to take place.

Important chemical constituents of soils. When any fertile soil is examined chemically, it is invariably found that there are present, in addition to water, the following elements : nitrogen, phosphorus, potassium, calcium, and iron. These substances are not present in the elementary state but as compounds ; the nitrogen is combined as ammonia (NH_3) or as organic matter, or as salts of nitric acid (nitrates). The phosphorus occurs as phosphates ; the potassium as potash salts ; the calcium as lime salts (such as chalk), and the iron chiefly as oxide, or hydrate, of iron.

Whenever a soil, be it clay, sand, or loam, is capable of producing a good crop, the above constituents are always present. A good farmer takes great care that the compounds are present in satisfactory proportions. It is chiefly the compounds containing nitrogen, the phosphates, and the potash which are deficient, as they are used up by crops to a much greater extent than are the other constituents. The latter part of this statement should be specially noted, as it is equivalent to saying these substances are most likely to be deficient.

It is not sufficient for the constituents to be merely present ; they must be there in such a form that the plant can use them. In many cases, the reason why some soils will not produce good crops is not actual absence of these constituents, so much as deficiency in solubility. Remember that all plants must have their food in solution ; therefore, if sufficient food is present in an insoluble form, the result is practically the same as if no food was present at all.

The reaction of soils. When a small portion of soil is shaken up with water in a bottle, filtered, and tested with litmus paper, it is generally found to have a neutral or alkaline reaction. Some soils, however, of a peaty nature, give acid solutions when treated in this way. This chemical reaction of a soil is very important; for a fertile soil must be quite neutral or slightly alkaline. The organisms which bring about various chemical changes in soils flourish best in a neutral or alkaline medium; hence the importance of keeping a soil alkaline. A good rough test for the absence of acid is to treat about 5 grams of soil with dilute hydrochloric acid. If the soil fizzes or effervesces briskly, giving off carbon dioxide, it cannot be acid, as the fizzing is due to the action of the acid on chalk which is present, which would have neutralized any natural acidity.

Soluble and insoluble matter in soils. When a little soil is shaken up with distilled water, and then filtered, it is found, upon examining the filtrate, that some of the soil has dissolved. It is not so much the actual amount of soil that dissolves in the water which is important, but rather the fact that some of it does dissolve. The amount which dissolves is very small; yet it is from this that plants have to obtain all their mineral matter (inorganic food). The insoluble portion is not of much use to plants, that is, when insoluble, because plants can only take in their mineral food in solution; but this insoluble matter may undergo change and become soluble. During the cultivation of land, this takes place; in fact, one of the chief objects of cultivation is so to change the insoluble particles so that soluble compounds are produced, which can then be absorbed by plants.

Uses of soils. Soils are used for the purpose of crop production. They possess the great advantage of being convenient to work, providing good support for the plant

(that is, holding it in position), and containing a large supply of plant food. Soils act as a laboratory in which very complicated changes take place. The compound nature of soils necessarily results in such complex changes continually proceeding. The actual nature of many of these is unknown, but the general result is that some of the insoluble matter is changed to soluble plant food. Further, it is possible to grow the same crops upon the same land year after year without any manure, although, as might be expected, the weights of the crops decrease under these conditions. We may, however, conclude from this that soils act as a storehouse for plant food. The store of food may not and is not all in a soluble, that is, available form, but weathering agents provide available food from the reserve material present in the soil; that is, food which can be used directly by plants.

Good and bad soils. Some soils will produce good crops, while others, no matter how they are treated, will not. The first are known as fertile soils; while the bad soils are said to be infertile, or sterile. There are soils which will not produce cultivated crops. These are faulty in some way. The most important soil faults are:

1. **Lack of plant food.** This is not a very common fault, except in desert sands.

2. **The particles may be so fine that air and water cannot permeate.** The tendency therefore is for such soils to be water-logged. When such is the case, the organisms present cannot obtain sufficient air to live. This deficiency results either in their death or such a serious check to their development that they become practically useless.

3. **Sourness.** If a soil is acid, useful organisms cannot flourish. Sourness is brought about by excess of water and lack of air.

4. **Too little water present,** due either to deficient rainfall or excessive evaporation.

Faults and remedies. The first step towards remedying the defects stated under Nos. 2 and 3 in the last paragraph is to get rid of excess of water. This is done by surface drainage or by means of tile drains underground. All attempts at improvement of such land fail unless drainage is first carried out. When superfluous water is drained off, air enters the soil to take its place. Roots and bacteria can in these circumstances obtain what they require for full development.

Effects of drainage. The following are the important improvements effected by drainage :

1. Excess of water is removed from soils.
2. Rain water is rendered more available for crops, as the water at once percolates into the soil and is not evaporated to the same extent as when it remains near the surface.
3. Crops are less liable to be affected by drought, as they can penetrate further into the soil, thus becoming more resistant to long spells of dry weather.
4. The **water-table** (that is, the level of permanent water) is lowered. The water round the roots of plants is, therefore, not stagnant acid nor sour.
5. Air follows the percolating water. Roots require air.
6. The texture of the soil is improved, for two reasons : (1) the water in sinking into the soil carries down lime salts, which flocculate (or flake) the finer particles, rendering the soil more porous. (2) Fine particles are carried down into the sub-soil, leaving the surface soil coarser and more fitted for crop production.
7. Drained land is ideal for the growth of nitrate-forming bacteria. Undrained land is suitable for nitrate-destroying organisms.
8. A greater variety of crops can be grown. On wet land only a few grasses of poor quality will grow. On drained land practically all cultivated crops will flourish, provided other essential conditions are satisfied.

After drainage, the acidity is neutralized by the addition of lime, the soil becomes more of a flaky nature (hence the name **flocculation** given to this effect of lime), and in a fit condition to produce cultivated crops.

How excessive loss of soil moisture is checked. In some cases, soils are apt to lose too much water, a result which may seriously affect crops growing upon

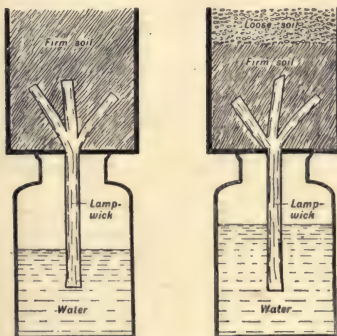


FIG. 23.—Experiment to show that water is saved by keeping the soil loose on the surface, that is, mulched.

them. When soils “dry out” in this way, steps are taken to conserve or keep the moisture. In order to prevent such loss, **mulching** is undertaken. This consists either in stirring the top two or three inches with a hoe or covering the surface with straw or manure. It will be found on examination of mulched soil that they are cooler and also contain more moisture; that is, they have lost less water from evaporation than soils not mulched. Such a saving in soil moisture is very important in districts where droughts are frequent (Fig. 23).

QUESTIONS.

1. What is soil ; and what use is it ?
2. What are sand, clay, and humus ? Discuss the importance of humus to (a) a sandy soil, (b) a clay soil.
3. Do soils contain living organisms ? If so, what use are they ?
4. What is meant by the texture of a soil ? Does it affect the growth of crops ? How ?
5. In what way does the specific heat of a soil influence its temperature ? What is the influence of temperature on crop production ?
6. How does the presence of water affect the temperature of a soil ?
7. Why are dark soils warmer during the day than lighter coloured soils ?
8. What are the important chemical constituents of soils ? Why are they important ?
9. What do you understand by the "available food" present in soils ?
10. Describe the characteristics of good and bad soils.
11. How does the action of frost assist the farmer to obtain a "tilth" on his heavier soils after they have been broken up in the autumn ?
12. Give a list of the substances plants obtain from the soil. Which of these are likely to be deficient, and why ?
13. What is flocculation, and what substances promote it ?
14. Mention the important improvements following the drainage of wet land.
15. The percentage of calcium carbonate in a soil tends to become smaller. How do you explain this ?

CHAPTER V.

PRINCIPLES OF MANURING : NITROGENOUS MANURES.

PRACTICAL WORK.

1. Obtain a sample of well-rotted farm-yard manure. Take about 10 grams in a porcelain basin ; dry it, and ascertain the percentage of water present. Now ignite the residue. Does it char ? Is farm-yard manure an organic manure ? Why ? Continue the ignition until all carbon particles have disappeared. Add 5 c.c. of dilute HCl to the ash, and evaporate the mixture to dryness on the water oven. Heat it for five minutes over an Argand burner turned down low ; then dissolve the residue in warm dilute HCl, and filter. Test the filtrate for potash and phosphoric acid by the usual tests. Can you detect both ?

2. Heat a small portion of dried farm-yard manure in a test-tube with soda lime. Is ammonia evolved ?

3. Carry out exactly the same experiments with any green manures and refuse manures you can obtain.

4. Obtain specimens of nitrate of soda, sulphate of ammonia, nitrolim, and nitrate of lime. Examine them carefully by the naked eye and pocket lens. Test small portions of each for ammonia by adding caustic soda and warming the mixture. If ammonia is not given off, test for nitric acid by the usual tests. What conclusions do you arrive at as to the presence of nitrogen in these manures ?

Are these manures all soluble in water, and does the solution contain nitrogen as ammonia or nitric acid ?

Value of Manuring. A perusal of the work of the earliest writers on agricultural matters brings out quite clearly the fact that the application of manures to land, in order to increase the yield of crops, was considered of vital importance even in those times. Then, as now, land could be found which would produce a good crop without the application of any manure. In fact, at the Rothamsted Experimental Station, plots can be seen which are still producing crops, even though no manures have been applied for forty years. The question may, therefore, be asked: Why are manures applied if a fair crop can be obtained without their application? The answer to this is perhaps best given by asking another question: If by the application of manures to land the cropping power can be increased two or three fold, and if the crop produced amply repays for the money expended on manures, is it not worth continuing?

Again, the population of the country has greatly increased in recent years, and as a consequence more food is required; therefore, it repays every farmer to produce the greatest crop, at the least expense, and with the least injury to the soil. Anyone can produce heavy crops, given good seed, good soil, and ample manure; but it is only within the province of good farming, to produce the same heavy crop, while satisfying the above-mentioned conditions. Continuously to remove crops from land without returning to the soil an equivalent in manure is robbery, and must ultimately end in failure. It may not mean failure of the robber, but will certainly seriously affect his successor and the owner. Many a so-called prosperous tenant is a bad farmer, who lives at the expense of the soil of his landlord.

The practice of judicious manuring is therefore one which deserves very careful attention; and it is the object of this chapter to give the main features relative

to manuring and the chemistry of substances used as fertilizers.

Nature and function of manures. A manure is any substance, simple or compound, which is applied to land for the purpose of providing crops, either directly or indirectly, with available food. By available food is meant food which can be absorbed ; that is, soluble food.

Our cultivated plants require for full development nitrogen, phosphates, and potash. Other substances are necessary for healthy growth, but in most cases the soil contains an ample supply of them.

In virtue of the fact that plants withdraw from the soil the three above-named substances in by far the greatest proportion, it follows, as an obvious conclusion, that if healthy growth has to continue, it will be necessary to make up the deficiency of these constituents, either by rendering insoluble food in the soil soluble, or by the direct addition of manurial substances. To continue cropping without applying manure must ultimately result in the soil becoming remarkably deficient in the three important ingredients, and if continued for a length of time, lead to a serious diminution in its crop-producing capacity.

One may compare these three important substances required by plants with the bricks, mortar, and wood required for building a house ; and just as in house-building a preponderance of one of these materials would not make up for deficiency in another, so it is with the constituents required for growing plants. That is to say, excess of bricks will not make up for lack of mortar, just as excess of nitrogen will not atone for deficiency of potash. There must in fact be, in addition to quantity, a satisfactory proportion among the ingredients. It is this important point which is often forgotten in the manuring of farm crops.

The whole scheme of manurial experiments carried out at the present time, has for its object, not only to ascertain the quantities of nitrogen, phosphoric acid, and potash necessary to produce a full crop; but also *the proportion* in which these ingredients must be present to produce the said crop, at the least expense, and without diminishing the fertility of the soil. The proportion of these ingredients is of so much importance that Liebig in his work on Agricultural Chemistry states it as a law, in words to the following effect: "The constituent present in the least proportion determines the size of the crop." This is known as **Liebig's Law of Minimum**, and is the foundation of manuring for crop production.

Classification of manures. Manures may be classified in a variety of ways depending upon the basis used for the classification. Whatever system is used, there will generally be found some manures which do not fall strictly into any one class. This is to be expected considering their complex nature; but for general purposes the simplest classification is that which divides all manures into four groups as follows:

1. Farm-yard manure.
2. Green manure.
3. Refuse manure.
4. Concentrated manures commonly known as artificial manures.

Farm-yard manure. This is the solid and liquid excrements of farm animals, plus any litter or bedding. Its composition is very variable, owing to the numerous factors which enter into its production. Those of importance are as follows:

Food. Other things being equal, the richer the food fed to any animal the richer the dung. Thus, the dung of pigs is poorer than that from fattening bullocks, as the food given is poorer in quality.

The kind of animal. This has a remarkable effect on the quality of the manure. For example, horses are fed for the production of energy; that is, for their capacity to do work. A fat horse is seldom energetic. The food given to a horse is, therefore, not laid on as flesh, but is used up in repairing the tissue-waste incident to hard work. Very little of the manurial constituents present in food are retained by the horse, and as a consequence, the dung is relatively richer than that of the cow, from which much of the fertilizing matter is removed by the milk. In the case of fattening bullocks, the food is rich, and the dung is rich, but if the animals ceased to lay on flesh, the dung would be still richer.

The age of the animal. Young animals require for healthy growth a sufficiency of nitrogen for flesh, and phosphoric acid for bone formation. The food supplied is, therefore, to some extent depleted of these, the dung becoming proportionately poorer. Older animals do not abstract these constituents to the same extent, the dung gaining thereby.

Storage of manure after production. There is probably no single factor which affects the composition of farm-yard manure to the same extent as storage. The composition of farm-yard manure is such that it forms a favourable medium for the growth of organisms, capable of producing decomposition or rotting. These organisms, however, require for full development not only a suitable medium, but also satisfactory external conditions, such as air, moisture, and a suitable temperature. Provided that these conditions are satisfied, the manure heap decreases in volume, due to the oxidation of the carbon to carbon dioxide, which escapes as a gas, and of the hydrogen to water, which passes into the air as water vapour.

Other changes take place which are more complex than the above, the important being the reduction of nitrogenous

organic matter to ammonia, and the oxidation of the ammonia to nitrites, and finally to nitrates. Also, the inorganic constituents are somewhat affected; any potash compounds present are dissolved, and if any excess of water is present, these are lost in the dark-coloured drainage liquid, so prevalent round manure heaps.

That the above changes take place in any manure heap may be proved by noting at intervals the alteration in the volume, testing the dark liquid for potash; and when the heap is carted away, examining the escaping gases for ammonia. If reduction of all the nitrogenous organic matter is *not* complete (which is highly probable), ammonia may be detected by smell, or better, by holding reddened litmus paper near the heap. The litmus turns blue if ammonia is present. Nitrates may be tested for in the black liquid, as they are also soluble in water.

The storage of farm-yard manure to bring about rotting or decomposition is carried out in order that the nitrogen present in the complex organic matter may be converted into those compounds which crops can absorb. Given sufficient air, moisture, and a suitable temperature, the organisms present will change the nitrogen in the nitrogenous organic matter to nitrates, in which form it can be assimilated by plants. This is only one of the many reasons why manure is allowed to rot.

Other reasons of importance are less weight to cart to the field, greater ease in spreading, and a quicker effect upon the crop to which the manure is applied.

There are, however, objections to the storage of farm-yard manure, as it has been clearly proved experimentally that however great the care exercised in storing it, only one-half of the manurial constituents ever reaches the field, and in all too many cases much less than one-half. Some, therefore, are in favour of the immediate application of manure; and if it were always convenient, there

is a great deal to be said in its favour. Others now favour storing under cover and keeping dry, as under such conditions very little loss is experienced.

The composition of farm-yard manure. An average sample of farm-yard manure will contain 0.6 per cent. of nitrogen; 0.3 phosphoric acid; and 0.5 potash. Thus, one ton provides for manurial purposes 13.4 lbs. nitrogen, 6.72 lbs. of phosphoric acid, and 11.2 lbs. of potash.

As compared with many other compound manures containing the same constituents, farm-yard manure is relatively poor, but its value is not confined to its fertilizing ingredients. The physical effect, that is, the part it plays in improving the texture of soils, is so marked that any valuation of farm-yard manure on a chemical basis without taking into consideration its physical action, is extremely misleading. For this reason it is, strictly speaking, impossible to compare this manure with the so-called concentrated fertilizers, except from one point of view, that is, actual crop production.

Green manures. Any young growing crop can be used as green manure by merely ploughing or digging it in. The increase in the weight of a growing crop is largely due to the assimilation of carbon derived from the carbon dioxide of the air, and to the absorption of water plus nitrogenous compounds by the roots. The mineral salts in solution which enter the plant *via* the roots, form a small proportion (less than 10 per cent.) of the whole plant. Green manuring, therefore, increases the amount of nitrogenous organic (carbonaceous) matter in soils, and this is one important reason why it is practised. Any crop may be used as green manure, but, wherever possible, leguminous crops are chosen.

Advantages of leguminous crops for green manuring. A comparison of the roots of oats or any cereals with

those of beans, peas, vetches, or any leguminous crops, shows that the leguminous roots have **tubercles** upon them, while the cereals have none. This difference was noticed many years ago by Hellriegel, who carried out experiments to ascertain the functions of the nodules. His conclusions were to the effect that the tubercles are the home of certain bacteria, and that these possess the power of making use of the free nitrogen of the air, producing thereby nitrogenous compounds, which can be directly used as food by plants. Leguminous plants thus become nitrogen conservers; and it is for this reason that plants of this order are used so largely for green manuring.

Soils are very liable to become deficient in nitrogen compounds, due to the heavy drain upon them by growing crops; therefore, leguminous plants, with the aid of bacteria, tend to make good this loss.

Advantages of green manuring. The advantages of green manuring are both physical and chemical, and may be stated briefly as follows:

1. The nitrogenous organic matter of the soil is increased; thus food for bacteria is added, and nitrogen compounds are present for production of nitrates.

2. The texture of the soil is improved. The decay of the organic matter has a tendency to separate the soil particles, thereby greatly facilitating the passage of water, the ramification of roots, and the admission of air.

3. Plant food is conserved. If at any time the soil contains soluble nitrates, these are liable to be lost by the leaching of heavy rains. A growing crop prevents this by absorbing the soluble nitrates. There is, however, this disadvantage; the soluble nitrogenous food is changed by the plant into insoluble compounds which before they can again be absorbed must undergo nitrification. The advantages, however, outweigh this disadvantage, as it is better to retain soluble plant food in an insoluble form

(as it may at some future date become soluble) than to lose it altogether in the drainage water.

4. Water is retained. This is very important, as many crops suffer from lack of water in a dry season.

Refuse manures. These manures are either (a) by-products in the manufacture of some articles of commerce, (b) destructor refuse, town refuse, or sewage sludge, (c) slaughter-house refuse, (d) damaged foods. The important substances classified as above are as follows :

- (1) Greaves, hoof and horn meal, shoddy.
- (2) Destructor refuse, sewage sludge, and night soil.
- (3) Dried blood, and slaughter-house refuse.
- (4) Damaged cakes and meals.

In many cases, these are only to be obtained at a reasonable price in localities where produced. A brief description of them is all that is necessary.

Greaves. This is the residue obtained when various kinds of flesh and fat are treated in order to obtain tallow and grease. The best and cleanest samples are used as food for poultry and are much esteemed. Greaves vary greatly in composition, depending upon the ingredients used in their manufacture. Average samples contain 4 to 6 per cent. nitrogen and usually about the same percentage of phosphate of lime. The percentage of phosphate of lime depends largely upon the amount of bone in the refuse; bones contain about half their weight of phosphate of lime commonly known as tri-calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$.

Hoof and horn meal. The chips and shavings obtained from button and comb factories form hoof and horn meal when powdered. Owing to their insolubility, these substances are not very rapid in action. They usually contain from 7 to 15 per cent. of nitrogen.

Shoddy. Shoddy cloth consists of old clothes remade into cloth. During the manufacture much material is rejected as being unfit or too short for remaking. This

forms the shoddy used as manure. Shoddy is a valuable article and is comparatively slow in its action. It possesses, however, the power of keeping the particles of soil separated for some length of time, thus materially improving the texture and assisting in the aeration of heavy soil. The percentage of nitrogen present may be anything from 2 to 15 per cent. Shoddy is, therefore, graded into low, medium, and high qualities.

Destructor refuse. Many town authorities burn the refuse from ash-pits, dust-bins, etc. ; others, after sorting, crush it into a more or less powdery mass. Both residues are used as manure. Their composition varies greatly, and of course depends entirely upon the quality of the initial refuse. Two samples of crusher refuse analysed in the author's laboratory gave only 0.5 per cent. of nitrogen and mere traces of phosphates and potash.

Sewage sludge and night soil. Sewage sludge is the sediment from sewage works, and night soil the contents of ash-pits and earth-closets. Sludge is generally poor in quality. Night soil is of much better quality, and may contain 7 to 8 per cent. nitrogen, 7 to 9 per cent. of phosphates, and 2 to 4 per cent. of potash.

Dried blood. Fresh blood contains about 80 per cent. of water, about 3 per cent. of nitrogen, and 0.3 per cent. phosphoric acid. Being too inconvenient and disagreeable to handle in the liquid state, it is dried. Dried blood contains from 12 to 15 per cent. of nitrogen and from 1 to 2 per cent. phosphoric acid.

Slaughter-house refuse. This is really slaughter-house sweepings containing varying proportions of dung, blood, meat, bone, hair, etc. It is a very variable substance, and should only be purchased on the basis of what it actually contains.

Damaged cakes and meals. The residue from oleaginous seeds after extraction of the oil may be used

as a feeding meal or pressed into cake and used as food. In some cases the resulting residues are unsatisfactory for feeding purposes, due to poisonous properties, in which case they are usually sold for manurial purposes. Cakes and meals which, when fresh and sweet, could be used as food, often become damaged by water or become too rancid for food. These are then used as manures. The percentage of nitrogen present rarely exceeds 7 per cent. phosphoric acid 3 per cent., and potash 2 per cent.

Concentrated fertilizers. These are commonly known as artificial manures, although many of them are natural products. They can be classified briefly as follows :

1. **Simple manures** ; that is, containing only one fertilizing ingredient ; either nitrogen, or phosphoric acid, or potash.

2. **Compound manures**, containing two or more of the above ingredients.

Further subdivision of **simple manures** gives the following :

(1) Nitrogenous Manures:

(2) Phosphatic „

(3) Potassic „

Nitrogenous manures. These manures supply nitrogen only. The important nitrogenous manures are nitrate of soda, sulphate of ammonia, nitrolim, and nitrate of lime.

Nitrate of soda (NaNO_3). In Chile (South America) immense beds of nitrate of soda are found. The natural salt is known as **Caliche**, and contains about 60 per cent. of pure nitrate of soda. The remaining 40 per cent. consists largely of common salt (NaCl), sulphate of soda (Na_2SO_4), sulphate of lime (CaSO_4), together with nitrate of potash (KNO_3), and sandy matter. The beds are only a few feet below the surface of the ground and are therefore quarried, not mined (Fig. 24).

Exactly how these nitrate beds were produced is not known. Some think the land was originally below the surface of the sea and became covered with seaweed. As the land gradually emerged from the sea, due to great earth movements, the seaweed nitrified. The nitric acid in the presence of the common salt found in sea water is said to have produced nitrate of soda. This theory is based largely upon the fact that caliche contains iodine, which is also found in seaweed. Others think caliche is



FIG. 24.—General view of nitrate of soda grounds and works.

the accumulation of ages of the washings from the mountainous region which is drained by the rivers flowing through the district. This again is conjectural. The area is practically rainless, and as such forms an excellent collecting area for soluble salts. In wet districts the accumulation would be practically impossible.

The crude salt (caliche) is obtained by digging, blasting, and quarrying. It is then dissolved in water, the insoluble matter separated, and the liquor evaporated slowly to dryness by the heat of the sun. The operation is carried out in large tanks erected for the purpose. The salt crystallizes easily (Fig. 25). It is then separated, dried, and packed in bags for export. The liquor remaining

contains a high proportion of compounds of iodine, from which iodine is extracted for technical purposes. In fact, most of the iodine of commerce is obtained from this source.

General characteristics of nitrate of soda. It is a salt easily soluble in water and deliquescent. It should, therefore, be stored in a dry place. As sold for agricultural



FIG. 25.—Nitrate of soda. Crystallizing pans.

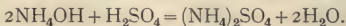
purposes, it usually contains about 95 per cent. of the pure salt, the remainder consisting chiefly of nitrate of potash (KNO_3), and common salt (NaCl).

Pure (100 per cent.) nitrate of soda contains 16.4 per cent. of nitrogen. A sample of 95 per cent. purity, therefore, contains 15.5 per cent. of nitrogen. It is usually sold under a guarantee of 15 to 15.5 per cent. of nitrogen.

Sulphate of ammonia $(\text{NH}_4)_2\text{SO}_4$. This is an artificially prepared salt produced by the neutralization of solution

of ammonia with sulphuric acid, or by passing ammonia into dilute sulphuric acid.

The equation representing the reaction is as follows :



Ammonium	Sulphuric	Ammonium	Water.
hydroxide.	acid.	sulphate.	

On the large scale, the ammonia is chiefly obtained during the purification of coal gas. The method is briefly as follows. Coal is placed in an iron retort and sealed

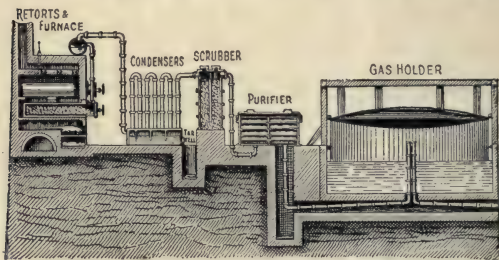


FIG. 26.—Gas works plant. The scrubbers absorb the ammonia, thus producing the ammoniacal liquor from which sulphate of ammonia is obtained.

to prevent access of air. The retort is heated externally, with the result that the coal undergoes decomposition. The process is technically known as the destructive, or dry, distillation of coal. The products obtained are gases (coal gas, plus impurities), liquids, including water, and semi-solids, such as coal tar. The residue left in the retort is coke (Fig. 26).

The coal gas thus obtained is very impure and a poor illuminant. The lack of lighting power is due to impurities present, of which ammonia is one. Ammonia does not burn unless heated to a high temperature, and even then gives out very little light. Coal gas has, therefore, to be

freed from ammonia, and this is done by passing it through water, the resulting liquid being known as **ammoniacal liquor**. When ammoniacal liquor is heated alone or with lime, ammonia is evolved, and when passed into sulphuric acid, produces crystalline sulphate of ammonia. Sometimes the sulphuric acid is added to the ammoniacal liquor, but the product obtained in this way is not nearly so pure as when the ammonia is driven off and passed into the sulphuric acid.

Pure sulphate of ammonia is white; but as prepared for agricultural purposes, it is generally not white, but varies from grey to almost black, due to impurities. The colour is not a very definite index to the quality. Some dark samples analysed are richer than many light coloured samples.

There are, however, other objections to the dark-coloured samples; they are sometimes sticky and difficult to spread by a manure distributor and occasionally contain poisonous compounds.

General characteristics of sulphate of ammonia. The pure salt, that is, 100 per cent., contains 21.21 per cent. of nitrogen; but as used for agricultural purposes, it usually contains about 20.4 per cent. of nitrogen, corresponding to a purity of 96 per cent. The salt is very soluble in water, 100 parts dissolving between 70 and 80 parts at 15° C. It occasionally contains sulphocyanides (salts of sulphocyanic acid, HCNS). Such salts are deleterious to crops; and if present in any quantity, the manure should not be used. This impurity is easily tested for; a few drops of ferric chloride solution gives a blood-red colouration with sulphocyanides.

Nitrate of lime, $\text{Ca}(\text{NO}_3)_2$. In 1898 Sir William Crookes, in his presidential address to the British Association for the Advancement of Science, directed attention to the gradual but certain exhaustion of the

natural beds of nitrate of soda, and pointed out that, in no very distant future, our crops, and especially wheat, must suffer in consequence of this lack of nitrates; but, he added, "Starvation may be averted through the laboratory."

The prospect of a failure of natural nitrates acted as an incentive to the production of an artificial salt possessing similar manurial properties. It has been estimated that the atmosphere contains 30,000 tons of nitrogen gas above each acre of the earth's surface. This enormous supply cannot, however, be used directly to any extent except by leguminous plants, to which class wheat does not belong. In order that the wheat crop may absorb nitrogen, it must be presented as a nitrate; that is, as a salt of nitric acid. Clearly, therefore, the task before experimenters was to find some method whereby the free nitrogen of the air could be made to combine with oxygen to form that oxide of nitrogen to which, when water is added, nitric acid is produced.

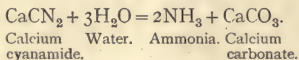
As early as 1775 Priestley had shown that, under the influence of the electric spark, free nitrogen would combine with free oxygen to form nitric acid. Electricity, however, was expensive, and for over a century no marked advance was made in the cheap production of nitric acid by direct combination of nitrogen and oxygen.

In 1902 an attempt was made to utilize the energy of the Falls of Niagara for the production of electricity, and also to produce nitrogen compounds from the nitrogen of the air. The company was known as the Atmospheric Products Co. It succeeded in producing nitrates, but the yield was too low to make the concern a success financially, and in 1903 operations were suspended. In the same year Dr. Birkeland, of Christiania, and Samuel Eyde, engineer, succeeded in so improving the electric furnace that it is now possible, by using waterfalls as driving

power, to produce nitric acid at a reasonably cheap rate. On neutralization of the nitric acid with lime, nitrate of lime is produced. As put on the market for agricultural purposes, it contains about 13 per cent. of nitrogen, while nitrate of soda contains about 15 per cent. The comparative prices are in proportion to the nitrogen. The salt is soluble in water, and is hygroscopic, so must be kept in a dry place. One important difference between this salt and nitrate of soda is, it provides lime as well as nitrogen. As many soils are deficient in lime, this is a decided advantage.

Nitrolim (or Calcium Cyanamide). Previous to 1898, when Sir W. Crookes threw out a warning as to a possible nitrate famine, Prof. A. Frank, of Charlottenburg, and Dr. Caro, had carried out experiments on the fixation of atmospheric nitrogen for the production of hydrocyanic (prussic) acid. Moissan in 1892 succeeded in producing calcium carbide, CaC_2 , cheaply by means of an improved electric furnace. Frank and Caro found that this carbide would absorb nitrogen, provided that no oxygen was present, the resultant product being either cyanide or cyanamide of calcium, depending upon the conditions under which it was produced. The cyanamide produced is not pure, but contains from 57 to 63 per cent. of calcium cyanamide, CaCN_2 , containing about 20 per cent. of nitrogen. In addition, it contains nearly 20 per cent. of free lime and 14 per cent. of carbon (which gives to it its black colour), and also a little siliceous matter. The mixture of calcium cyanamide, lime, carbon, and siliceous matter is sold as nitrolim or lime nitrogen. Its manurial action is similar to sulphate of ammonia, and it contains nearly the same proportion of nitrogen. On moistening calcium cyanamide with water, ammonia gas is evolved; in fact, the compound can be used as a source of

ammonia. The equation representing what takes place is as follows :



This is in all probability what takes place when it is applied to soils. The soil moisture would liberate ammonia, which in turn would be nitrified, thus becoming available for crops. A third process of rendering atmospheric nitrogen available is known as the Haber process, which uses nitrogen from the air and hydrogen from water. By means of great pressure these gases are made to combine to form ammonia, NH_3 , from which ammonium sulphate is produced.

Comparison of cost of nitrogenous manures. If nitrate of soda, sulphate of ammonia, nitrate of lime, and nitrolim are offered at different prices per ton, a comparison resolves itself into ascertaining which manure is cheapest in proportion to the nitrogen present.

Taking nitrate of soda containing 15 per cent. of nitrogen at £10 per ton, and sulphate of ammonia containing 20 per cent. of nitrogen at £13 per ton, it will be seen that if the price per ton is divided by the percentage of nitrogen, we get the cost of 1 per cent. or a unit of nitrogen. In this case the unit of nitrogen in nitrate of soda costs 13s. 4d. and in sulphate of ammonia 13s. ; therefore at these prices sulphate of ammonia is the cheaper by 4d. per unit. If there is a choice of nitrogenous manures, it is only necessary to find the cost of a unit of nitrogen in each manure and make use of the cheapest ; provided that the manure chosen is suitable for the crops to which it is about to be applied. If it has been proved by experiment that it is practically immaterial which is used, then the price per unit would no doubt decide which to purchase.

QUESTIONS.

1. What is manure ?
2. Mention the factors which influence the composition of farm-yard manure.
3. What are green manures, and the advantages arising from their use ?
4. Name some important refuse manures, and state what information you would require before purchasing such manures.
5. What are concentrated fertilizers ? Name those of importance containing nitrogen.
6. Classify concentrated fertilizers under the following heads : (a) those found naturally, (b) those prepared artificially.
7. What manures have lately been prepared from atmospheric nitrogen ?
8. How would you detect the presence of (a) sand, (b) common salt, in a sample of sulphate of ammonia ?
9. Write a short account of the manufacture, composition, and uses of the various nitrogenous manures.
10. Give the average composition of farm-yard manure. What circumstances influence the composition ? State how you would treat the manure made by fattening oxen to avoid as far as possible loss of valuable constituents.

CHAPTER VI.

PHOSPHATIC, POTASSIC AND COMPOUND MANURES.

PRACTICAL WORK.

1. Examine specimens of bones, bone meal, super-phosphate, and basic slag. Note carefully any physical characteristics, such as colour, weight, and structure, when the manure is examined by a lens. Compare the weights of equal bulks, and state which is the heaviest.

Take about 5 grams of each and shake them up with distilled water. Filter the mixture and test the filtrate for phosphoric acid. Which manures contain most soluble phosphate? Now add 100 c.c. of 2 per cent. solution of citric acid to the residues, and shake the mixture at intervals for half an hour. Filter and test the filtrates for phosphates. Which manure gives the heaviest precipitate?

Dissolve the insoluble matter on the filter papers in dilute nitric acid, warming to assist the solution. Filter the mixture and test the filtrate for phosphates soluble in dilute nitric acid.

Use your results to arrange the manures in the following order :

- (1) Those containing water soluble phosphates.
- (2) Those containing citric soluble phosphates.
- (3) Those containing phosphates soluble in nitric acid.

These results are very important, so you should try to remember the order of solubility.

2. Obtain and examine specimens of compound manures commonly sold as turnip, potato, or mangold manures,

or garden fertilizers. Experiment with them just as you did with farm-yard manure. State whether they contain nitrogen, phosphates, and potash.

Simple phosphatic manures. These manures contain only one manurial ingredient, namely, phosphoric acid. The most important are bones, superphosphate, basic slag, and basic superphosphate.

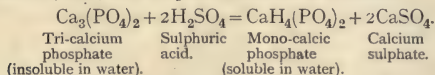
Bones. Raw bones, or, as they are sometimes called, green bones, contain about 35 per cent. of organic matter and 65 per cent. of mineral matter. The organic matter contains between 4 and 5 per cent. of nitrogen and the mineral matter from 45 per cent. to 50 per cent. of phosphate of lime, technically known as tri-calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$.

When first used as manure, bones were simply broken into pieces varying in size, inch, half inch, quarter inch, and so on. Farmers soon discovered that the finer the bones the quicker their action. It is, however, difficult, owing to the organic matter present, to grind raw bones very fine. The organic matter can be removed by boiling and steaming, thus giving boiled and steamed bones. The organic portion removed consists largely of fat and gelatine. The fat is used for soap and candle making, and the gelatine for glue.

The bones after being freed from organic matter are easily ground into coarse powders or fine meals; thus we get **bone meal** and **steam bone flour**. The composition varies with the perfection of extraction of the fat and gelatine. Bone meal has usually had all the fat extracted, but very little of the gelatine. It contains 4 to 5 per cent. of nitrogen, and between 48 and 51 per cent. of phosphate of lime; while steam bone flour, having had most of the gelatinous matter removed, contains only about 1 per cent. of nitrogen, but a higher proportion of phosphates than the bone meal, that is to say, from 60 to 70 per cent.

Bones may also be burned, thus depriving them of the organic matter and leaving bone ash, or, as it is sometimes called, **bone phosphate**. Bone phosphate (tri-calcium phosphate) is insoluble in water, and as such is very slow in its action. To remedy this defect bones were formerly dissolved in sulphuric acid. The resultant product, known as dissolved bones, was not very satisfactory, as it was generally sticky, due to the compound produced by the action of the sulphuric acid on the organic matter. To improve it in this respect gypsum was added, as it renders the mass powdery, thus facilitating sowing.

The action of the sulphuric acid upon bone flour or ash can with care be made to produce a friable product in which the phosphoric acid is in a much more soluble form than in the original bones. The equation representing the reaction between the tri-calcium phosphate present in bone ash, etc., and sulphuric acid is as follows :

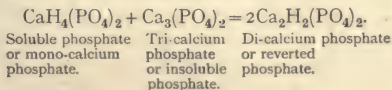


The addition of sulphuric acid to bones in order to render the phosphate of lime more soluble was carried out in the early nineteenth century, but it was not until 1840 that it really became of practical importance. Liebig mentioned it in 1840 and in 1842 Mr. John B. Lawes, later Sir John Lawes, the founder of the famous Rothamsted Experimental Station, took out a patent for the manufacture of dissolved bone ash. The resultant product was known as **superphosphate**, as it was found on analysis to contain a higher proportion of phosphoric acid to lime than was present in the original tri-calcium phosphate of the bone ash ; that is to say, treatment with sulphuric acid removed some of the lime from the tri-calcium phosphate leaving the remainder superphosphated. An examination of the above equation explains what takes place.

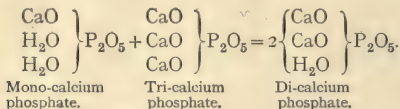
Superphosphate. At the present time superphosphate is prepared not from bone ash, bone meal, or bone flour, but from phosphatic rocks found in various parts of the world. The chief deposits are in the United States, Canada, Spain, and Algeria. These mineral phosphates contain tri-calcium phosphate varying from 50 to 80 per cent. When ground and treated with sulphuric acid in correct proportions, mineral or ordinary superphosphate is produced. The method of manufacture is comparatively simple. The rock phosphate is ground in a mill to a fine powder, treated in a mixer with the requisite amount of acid, then transferred to a pit or "den" until the reaction is complete. Later it is spread out on a floor to dry and is then ready for use as superphosphate. Needless to state, the proportion of sulphuric acid must be accurately gauged, as the addition of too little would result in only a proportion of the tri-calcium phosphate being acted upon, while too much would cause the manure to be wet, sticky, and very acid, thus rendering sowing difficult, besides endangering the hands of the sower or the machine used in distributing it.

Superphosphate as now sold usually contains from 25 to 27 per cent. of superphosphate of lime, called soluble phosphate, $\text{CaH}_4(\text{PO}_4)_2$, and between 2 and 4 per cent. of unaltered tri-calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$. The less it contains of the latter the better, because the two tend to react, producing an intermediate phosphate, known as di-calcium phosphate, $\text{Ca}_2\text{H}_2(\text{PO}_4)_2$, commonly called reverted phosphate.

The equation representing the reaction between soluble phosphate and tri-calcic phosphate is as follows:



The following equation will perhaps be more easily understood :



Mono-calcium phosphate is soluble in water, tri-calcium phosphate is insoluble, while di-calcium phosphate is partly soluble, and is, in fact, soluble in very dilute acid solution (2 per cent. citric acid).

The presence of iron salts or salts of alumina also tends to produce reversion ; hence the objection raised to the presence of iron and alumina in the natural mineral phosphates.

Superphosphate is valued entirely on the percentage of soluble phosphate present or rather upon the percentage of tri-calcium phosphate rendered soluble. It is important to remember this. For example, a superphosphate sold as containing 25 per cent. soluble phosphate does not mean that it contains 25 per cent. of $\text{CaH}_4(\text{PO}_4)_2$, but 25 per cent. of $\text{Ca}_3(\text{PO}_4)_2$ which has been rendered soluble, that is, changed to $\text{CaH}_4(\text{PO}_4)$ by the action of sulphuric acid.

Basic superphosphate. Superphosphate is acid, and as such is not a satisfactory manure to apply to soils deficient in lime, as it makes them still more deficient by reacting with any lime or carbonate of lime present, but unacted upon. To remedy this, superphosphate is sometimes treated with lime, thus rendering it basic ; hence the name basic superphosphate. The proportion added is sufficient to convert the mono-calcium phosphate into di-calcium phosphate, and to leave a slight excess of lime.

Basic slag, basic cinder, or Thomas phosphate powder. Previous to the year 1879, several beds of iron

ore found in England could not with advantage be used for the preparation of steel owing to the presence of phosphorus in the ore. Unless phosphorus is extracted, steel has a tendency to become "short," that is, it snaps easily on bending. In 1879 two experimenters, Thomas and Gilchrist, discovered that when iron contaminated



FIG. 27.—Blast furnaces in which ironstone is smelted, and from which basic slag is obtained.

with phosphorus is heated in furnaces lined with basic bricks (*i.e.* bricks containing calcium and magnesium carbonate), the phosphorus combines with the lime to form a phosphate of lime, which phosphate was then found in the slag obtained from the furnaces (Figs. 27 and 28).

A few years after this discovery, experiments were tried in order to ascertain if the slag had any manurial value. The results were so remarkable both in England and abroad that slag heaps at once became valuable. It was, however,

found that unless the slag was finely ground the results were not satisfactory. Slag as at present placed on the market is ground very fine. The usual guarantee as to fineness is, that 80 per cent. of it will pass through a sieve of 10,000 meshes to the square inch.

The only constituents of basic slag which are of value to the farmer are phosphoric acid and lime. Other



FIG. 28.—Limestone being added to the converter to remove the phosphorus from the pig iron, and form basic slag.

constituents present are oxides of iron, aluminium, manganese, silicon, and magnesium, with traces of sulphur. Lime is usually present to the extent of about 40 per cent., but only between 1 and 8 per cent. is present as free lime; the remainder is in combination with the phosphoric acid as phosphate of lime. Exactly what phosphate of lime is present in slag appears to be a matter of doubt. It is generally stated to be $(\text{CaO})_4\text{P}_2\text{O}_5$ (tetra-calcium phosphate) but later researches prove it is a highly complex silico-phosphate, probably $(\text{CaO})_5\text{FeOSiO}_2\text{P}_2\text{O}_5$.

As put on the market, slag is a heavy blackish powder. When it is shaken up with water, the solution is basic, hence the name basic slag. In composition it varies greatly; some samples contain only 20 per cent. of phosphate of lime (calculated as tri-calcium phosphate and not as tetra-calcium phosphate), while others contain nearly 50 per cent. The phosphate is only very slightly soluble in pure water, but generally about 80 per cent. of it dissolves in a 2 per cent. solution of citric acid; hence the name "citric soluble phosphate of lime." While not, therefore, like superphosphate (soluble in water), it is soluble in dilute acid solution and as such is more readily available than such substances as bones or mineral phosphates.

Potash manures. Potash (K_2O) is found in all fertile soils combined with either organic or inorganic acids. Many minerals containing potash take part in the formation of soils, the important group being feldspars. Potash feldspar is a complex compound containing potash alumina, and silica, $K_2O_3SiO_2Al_2O_33SiO_2$.

When potash feldspar "weathers" the potash is acted upon by the carbon dioxide of the air, producing carbonate or bicarbonate of potash. These salts are soluble in water and may, therefore, be washed away. The remainder, that is, the silicate of alumina, when hydrated, becomes clay. Thus clay may, or may not, contain potash salts; pure clay does not, but impure, that is, agricultural clay, does. Wild plants have this source of potash upon which they may draw continually. Cultivation, however, has so increased the yield of crops that the amount of potash produced by weathering is inadequate for their production. Potash has, therefore, to be applied artificially, that is, as manure.

Simple potash manures. Until the year 1861 the chief sources of potash were wood ashes, kelp (ashes of sea-weed),

and saltpetre. Wood ashes were formerly collected for manurial purposes. **Kelp** was treated with water to dissolve out potash salts. On evaporation crude "potashes" were obtained. **Saltpetre** is found as an

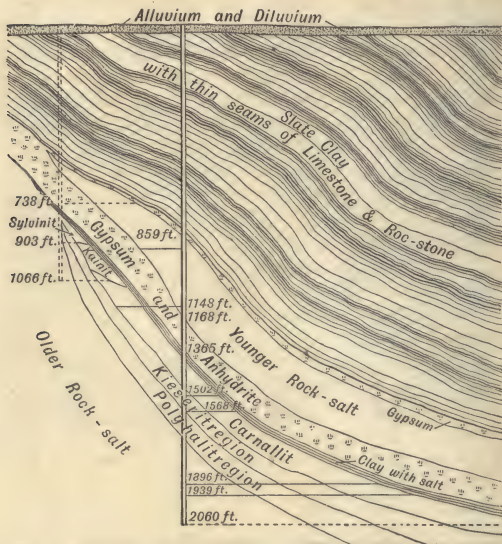


FIG. 29.—Geological section of German potash beds.

incrustation on the surface of the ground in Egypt, India, and other hot countries. About the year 1839 enormous beds of potash salts were discovered at Stassfurt in Germany. In 1862 the beds began to be worked on a commercial scale. At present these are the only important potash beds known. The chief salts of agricultural

value obtained from these mines are kainit, sulphate of potash, and muriate or chloride of potash (Fig. 29).

Kainit. This crude salt consists of sulphate and muriate of potash (K_2SO_4 and KCl), together with sulphate of magnesia ($MgSO_4$), chloride of magnesia ($MgCl_2$), and common salt ($NaCl$). Kainit is usually represented by the symbols $K_2SO_4MgSO_4MgCl_2H_2O$. As put on the market kainit is a many-coloured crystalline salt soluble in water, with the exception of a very small proportion of siliceous matter present as impurity. From the agricultural point of view, the important feature of the salt is that it contains between 12 and 13 per cent. of potash (K_2O).

Sulphate of potash (K_2SO_4). This salt is not found pure, but is separated from natural mixtures containing it. As used agriculturally, it is generally about 90 per cent. pure, corresponding to 50 per cent. potash. It is a biscuit-coloured salt which is soluble in water and is not deliquescent. As it contains about four times as much potash as kainit, its price is generally about four times that of kainit.

Muriate or chloride of potash (KCl). This compound is also separated from others with which it is found naturally, and is generally of 90 per cent. purity, corresponding to 58 per cent. potash. It is a white crystalline salt somewhat resembling nitrate of soda. It is soluble in water, and is slightly deliquescent.

Compound manures. These contain two or more of the important manurial substances, nitrogen, phosphates, and potash. Those of importance are natural guanos, fish guano, and meat meals; and a host of prepared mixtures varying in composition with the wish of the manufacturers and the object for which they are intended by the purchaser.

Natural guanos. On many islands in the Pacific Ocean,

notably those near Peru, in South America, thousands of sea birds congregate during the breeding season. Their droppings form very valuable manure. The climate of these islands is hot, with practically no rainfall; therefore the manure suffers little from leaching. The high temperature tends to dry these deposits, and as dryness is an excellent deterrent of decomposition, the manure produced remains rich in its original constituents. Guanos have been used in England since about 1840. When first introduced their quality was excellent, some samples containing 17 per cent. of nitrogen, 20 per cent. of phosphate of lime, and between 1 and 2 per cent. potash.

As the food of sea birds consists largely of fish, which are rich in nitrogen and phosphates, the dung of these birds contains a high percentage of those ingredients. As at present imported, guanos are not nearly as rich as formerly. They are generally more of the nature of fresh birds' dung, and as the desiccation and the complex changes taking place during desiccation have not proceeded to the same extent as in the older guanos, their composition, and the results produced on application, are not equal to the older samples. They are, however, extremely valuable manures, and provided the price is not too high, they are well worth attention for manurial purposes. It may be taken as a general rule that if nitrogen is high, phosphates will be low, and *vice versa*. Occasionally, sulphuric acid is added to render the phosphates more soluble and to fix any ammonia. When so treated, they are sold as dissolved guanos.

Fish guanos and meat meal. The residue from fish-curing stations, when dried and powdered, is put on the market as fish guano or fish meal. Its composition depends upon the quality of the refuse. Some samples contain 8 per cent. of nitrogen and 16 per cent. of phosphates, while others contain practically no phosphate

and higher nitrogen. The variation is caused chiefly by the amount of bones present in the mixture. Various "Extracts of Meat" are prepared by pressing mixtures of meat and bone with or without the application of heat. The residues are sold as meat meal, and are used as manure. Like guano, their composition is variable, due to the relative proportions of meat and bone present. Usually they contain about 10 per cent. of nitrogen, and if in good condition, that is, dry and friable, they are very valuable as manures.

How to value manures. Like all other commodities, the actual market value of a manure depends largely upon the supply and demand for it. This is well illustrated in certain districts by the prices charged for farm-yard manure. Some years it can be purchased at 3s. 6d. per ton, while in the same district a year later 5s. per ton may be charged, if the supply is limited, or the demand increased. Similarly with regard to compound concentrated fertilizers. The farmer, however, is often faced with the fact that he has two manures of different composition offered at different prices, either of which will equally well serve his purpose; or he has a compound manure offered and he wishes to decide whether the price is in proportion to the ingredients present; or whether he can prepare a mixture containing the same percentages of nitrogen, phosphates, and potash, at a cheaper rate than that at which the compound manure is offered.

Consider an example. A compound manure is offered at £6 per ton guaranteed to contain 5 per cent. of nitrogen, 15 per cent. of soluble phosphate, and 3 per cent. of potash. Is it worth the money? The simplest method of answering this question is first to find the cheapest rate at which nitrogen, phosphates, and potash can be purchased in the simple nitrogenous, phosphatic, and potassic manures on the market,

Suppose nitrate of soda, containing 15 per cent. nitrogen, is offered at £10 per ton, and sulphate of ammonia, containing 20 per cent. nitrogen, at £13 per ton; then the nitrogen in the nitrate of soda costs 13s. 4d. per unit (that is, 13s. 4d. for each 1 per cent. present), and sulphate of ammonia, 13s. per unit. Obviously, therefore, if these are the only two nitrogenous manures available for comparison, nitrogen can be purchased in sulphate of ammonia at the cheaper rate at that period, that is, at 13s. per unit.

Soluble phosphate can usually be purchased at the cheapest rate per unit in superphosphate. If superphosphate is being sold at 50s. per ton, containing 25 per cent. soluble phosphate, the value per unit is 2s.

Potash in kainit is the cheapest source of that constituent. Kainit is generally sold on a guarantee of 12.5 per cent. potash at a price very close upon 50s. per ton. This is at the rate of 4s. per unit.

Using these prices (the cheapest for nitrogen, phosphates, and potash) as our basis of calculation, that is, nitrogen at 13s., soluble phosphate at 2s., potash at 4s., we can now estimate the value of the compound manures as follows:

Nitrogen, 5 per cent. at 13s., is worth	-	-	£	s.	d.
Soluble phosphates, 15 per cent. at 2s., is worth	-	-	3	5	0
Potash, 3 per cent. at 4s., is worth	-	-	1	10	0
	-	-	0	12	0
Total value			-	£5	7 0
Price asked	-	-	-	£6	0 0
Price in excess of actual constituents present if	-	-	-		
bought at cheapest rate	-	-	-	0	13 0

Some allowance should, however, be made for mixing the compound manure, as it would cost the farmer a few shillings per ton if he had to mix it. However, 13s. is too

much for mixing ; therefore, the manure at £6 is too dear by approximately 10s. per ton.

In this way, using simple manures as standards, it is possible to ascertain the actual value of any compound manure on the market, and consequently to decide which of the two manures is the cheaper if we value both on the same basis.

QUESTIONS.

1. What are superphosphate and basic slag ? State briefly how they are prepared.

2. In what forms are bones used as manure ?

3. What are the usual guarantees of nitrogen in nitrate of soda and nitrate of lime ? Also phosphates in superphosphate, basic slag and bone meal ; and potash in kainit, sulphate of potash, and muriate of potash ?

4. What is guano ?

5. If nitrate of soda containing 15 per cent. of nitrogen is offered at £10 per ton, and sulphate of ammonia containing 20 per cent. nitrogen at £13 per ton, which is the cheaper per unit of nitrogen ?

6. A manure containing 5 per cent. nitrogen, 6 per cent. soluble phosphate, and 2 per cent. potash, is offered at £4 10s. per ton. Is it cheap ? Take as a basis the present prices of nitrate of soda or sulphate of ammonia for nitrogen, superphosphate for the soluble phosphates, and kainit for potash. The prices can be obtained from any agricultural paper.

7. A grey substance is found to be acid to litmus and partly soluble in water. The clear solution gives a yellow precipitate with a nitric acid solution of ammonium molybdate. What would you consider the nature and manurial properties of the substance ?

8. What are the chief sources of (a) potash manures, (b) mineral phosphates, (c) sulphate of ammonia ?

CHAPTER VII.

FARM FOODS : NATURAL GRASSES, CLOVERS, OIL SEEDS AND NUTS.

PRACTICAL WORK.

1. Obtain samples of the following seeds : wheat, barley, oats, rye, beans, peas, linseed, cotton seed, soya beans, earth nuts (monkey nuts), and, if possible, palm nuts and dried coco-nut (copra). Make yourself thoroughly acquainted with their appearance and that of as many other useful farm seeds as possible. Also examine as many specimens of weed seeds as you can procure. Weed seeds are occasionally used to adulterate meals and cakes ; hence the necessity for knowing them.

2. Grind, or powder, about 20 grams of any one of the above samples and carry out the following experiments with the meal obtained.

3. Dry 2 grams, and ascertain the percentage of moisture. Extract the dry residue with small portions of ether, say 10 c.c., repeating the process five times. Evaporate the ether solution over hot water (*not over a flame*), and when dry, weigh the residue. This is roughly the oil or fat present in two grams of the sample. Calculate the percentage.

4. Treat the residual meal with 120 c.c. of 1.25 per cent. solution of H_2SO_4 ; boil it for thirty minutes ; dilute it to 500 c.c., and strain it through fine linen, collecting on the linen all the insoluble matter. Wash this residue three times with hot water. Now wash it off the linen with

120 c.c. of 1.25 per cent. solution of caustic soda ; boil it for thirty minutes ; dilute it to 500 c.c. ; cool and strain it again through the same linen. Wash the residue well with hot water three times ; then with very dilute HCl once ; and again with hot water three times ; and once with alcohol.

Scrape the residue from the linen into a crucible, dry it till constant, and weigh it. This is the "insoluble fibre," plus a little ash, which you may neglect.

5. Reduce to ash five grams of the same meal and calculate the percentage of ash. You have now estimated water, oil or fat, insoluble fibre, and ash ; the remainder consists of protein or albuminoids and carbohydrates (such as sugar and starch).

Albuminoids and carbohydrates are both rather difficult to estimate, especially the carbohydrates ; so it is wise to estimate the albuminoids and find the carbohydrates by difference. The estimation of albuminoids is rather advanced for beginners, but a brief description of the method may be interesting. Those who from the following description cannot carry out the work, should consult more advanced works on practical chemistry which enter into greater detail.

6. Take one gram of meal ; place in a round bottom flask of 500 c.c. capacity. Add 20 c.c. strong H_2SO_4 ; warm the mixture for ten minutes, then boil it over a naked flame, keeping the flask inclined while heated. After boiling it for 15 minutes, add 8 to 10 grams of powdered potassium sulphate. Continue the heating until the liquid is a very pale straw colour or practically colourless. Note that the hot sulphuric acid chars the meal, and on further heating the black carbon particles are oxidized. The sulphate of potash raises the boiling point, thus materially assisting the oxidation, as the higher the temperature the quicker oxidation takes place. Any nitrogenous matter of the nature of albuminoids, present in the original meal, is now in the liquid as sulphate of ammonia. If the liquid be diluted and made alkaline with caustic soda, ammonia is liberated, and if this is

collected in standard acid, its amount can be ascertained by titrating the standard acid before and after absorbing the ammonia. As $\frac{14}{17}$ ammonia is nitrogen, it is easy to calculate the nitrogen after ascertaining the ammonia. The percentage of nitrogen present in the meal, multiplied by 6.25, gives the percentage of albuminoids.

7. Add 2 grams of the meal to 100 c.c. of boiling water, and continue boiling for five minutes; then filter. Add a few drops of tincture of iodine. If starch is present, blue or black iodide of starch is formed.

8. Grind and examine as many different seeds as time will permit, and examine the solution of the said meals for starch. Does linseed contain starch? If not, will not this test detect the adulteration of linseed cake or linseed meal with any of the seed containing starch?

9. Take two samples, of about 50 grams each, of any of the above meals so prepared; to one add a pinch of ordinary mustard. Make both samples into a paste with water, and set aside the beakers in a warm place for half an hour. Keep the beakers covered with paper or glass plates, and after half an hour remove the plates. Can mustard be detected by its smell under these conditions? This simple test is used for detecting mustard seed in cakes and meals.

Farm foods. All farm foods contain the following ingredients: moisture, oil, albuminoids or proteids, amides, carbohydrates, insoluble fibre and ash.

1. **Moisture.** No farm food is absolutely dry, although some may appear so. The percentage of water varies from 5 per cent. in very dry meals to 75 per cent. in such food as wet brewers' grains.

2. **Oil.** This ingredient consists of glycerine combined with various acids, known as fatty acids, and oleic acid, as they are characteristic of fats and oils. Fats and oils are therefore glycerides of fatty acids. Good examples are linseed oil, cotton-seed oil, earth-nut oil, which are

obtained by pressure from linseed, cotton seed, and earth nuts respectively. Oil contains no nitrogen.

3. Albuminoids or proteids. These nitrogenous compounds are produced only in plants. They are extremely complex, containing approximately 53 per cent. of carbon, 7 per cent. of hydrogen, 16 per cent. of nitrogen, 21 per cent. of oxygen, and 1 per cent. of sulphur. They closely resemble similar substances found in the flesh of animals; in fact, the albuminoids of plants, when assimilated by animals, undergo very little change when laid on as flesh.

4. Amides. These are nitrogenous substances of a non-proteid nature. When proteids undergo decomposition, amides are produced. Also, the first products formed from the soluble nitrates absorbed by the roots of plants are of an amide nature. Amides may therefore be classed as nitrogenous substances on the road to real proteids, as well as decomposition products of proteids. They have not the same value for flesh production as proteids. Young succulent plants and roots contain most amides; while mature plants, roots, and seeds contain a higher proportion of proteids.

5. Carbohydrates. Carbohydrates consist of carbon combined with hydrogen and oxygen in the same proportion as found in water; hence the name. Good examples are starch ($C_6H_{10}O_5$), cane sugar ($C_{12}H_{22}O_{11}$), dextrin ($C_6H_{10}O_5$), and cellulose ($C_6H_{10}O_5$).

6. Insoluble fibre. On treatment of a small portion of finely ground cake or meal with dilute acid (1.25 per cent.), followed by dilute alkali of the same strength, a residue is obtained consisting of fibre with a small proportion of nitrogenous matter, plus ash. The fibre consists chiefly of cellulose—a substance similar in composition to ordinary filter or blotting paper. The above treatment aims at separating the fibre, which would not be attacked by the digestive juices of animals; hence the name

sometimes applied to it, "indigestible fibre." Such, however, is not now regarded as quite true, as it is well known that some of the so-called indigestible fibre can be, and in fact is, digested. The proportion of insoluble fibre is, however, a guide to the amount of energy required in digestion. Foods containing much insoluble fibre are more difficult to digest than others containing less.

7. Ash. The ash or mineral matter of farm foods generally varies between 5 and 10 per cent. The important ingredients are potash, lime, and phosphoric acid; but iron, alumina, chlorine, and manganese are usually present also. Young animals require phosphoric acid and lime for the formation of bone. Animals cannot live for any length of time upon food destitute of mineral matter, but the exact part played by each mineral element in the animal economy is not accurately known.

Classification of farm foods. Farm foods may be classified as follows :

1. Natural grasses, clovers, and other leguminous crops and seeds.
2. Oil seeds and nuts, either before or after extraction of a portion of the oil.
3. Cereal grains and their by-products.
4. Roots, and green food such as cabbages.
5. Mixtures of the above, commonly known as compound feeding stuffs.

Natural grasses and clovers. Grasses and clovers, not being ripe products, vary greatly in composition. The causes of this variation are as follows :

1. Soil and manure. Soils vary much as regards the quality of the herbage produced. Fields are known where the grasses which flourish upon them will fatten bullocks without artificial feeding by cake. One striking example is the marsh land near Pevensey in Sussex. Exactly what gives rise to the high feeding value of this herbage

is not known. As might be expected, manuring affects the quality of grass. Nitrogenous dressings increase the percentage of albuminoids, but if carried too far, amides are produced in preference to true albuminoids.



FIG. 30.—Meadow fescue.

The marked effect of basic slag on the growth of clovers on heavy pasture land is well known. The explanation usually given is that basic slag contains phosphoric acid and free lime. Clovers require both; also potash and nitrogen. Heavy land contains potash, usually in sufficient proportion for clovers. The lime in the slag liberates the potash; and as clovers are able to assimilate the free nitrogen of the air, the application of slag on heavy land amounts indirectly to a full manuring.

2. **Nature of herbage.** As clovers are practically half as rich again as grasses, their presence in either pastures or meadows materially increases the feeding value. The presence of rich grasses like meadow fescue,



FIG. 31.—Timothy grass.

Timothy, cocksfoot, and rye grass exercises a marked influence upon the quality of the herbage, while others, such as soft brome and bent-grass, have the opposite effect. (Figs. 30 to 34.)

3. **Age when cut.** The younger the grass when cut, the richer and more digestible it is. Taking weight of crop into consideration, it is found that the greatest amount of food is obtained if the grasses are cut when just in flower. The season, however, exercises a marked influence

upon the quality. A long period of continuous warmth

ITALIAN RYE GRASS

(*LOLIUM ITALICUM*)



FIG. 32.

is reflected in an increased percentage of albuminoids; while a cold season has the opposite effect.

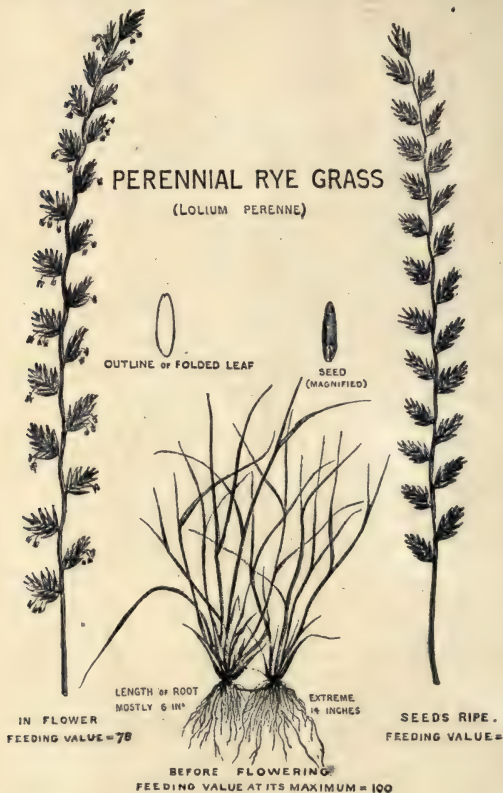




FIG. 34.

4. **Harvesting and stacking.** Perhaps no one external condition affects the quality of the hay produced more than its harvesting and storage. Bad weather during haymaking is always a serious matter, and may in fact more than counterbalance any good effects accruing from an excellent growing season. Good haymaking resolves itself into drying the grass with as little movement as possible. Bad weather, however, necessitates such movement with consequent loss due to breaking off the finer and more nutritious leaves, as well as further loss due to leaching. Well-made hay properly stacked undergoes slight fermentation, resulting in the production of more soluble compounds than originally present, coupled with the formation of pleasant volatile compounds, which give to good hay its characteristic smell.

Damp hay when stored undergoes further fermentation than that named, giving rise to acidity or sourness. Fungi also develop to a great extent, producing mouldy hay which is not relished by stock, and in many cases is responsible for stomach and intestinal trouble when given as food.

Composition of grasses and clovers.

Grasses or Clovers.	Oil.	Albu- minoids.	Carbo- hydrates.	Fibre.
	Per cent.	Per cent.	Per cent.	Per cent.
Cocksfoot - - -	1·00	1·75	—	16·00
Meadow fescue - - -	1·00	1·13	—	12·50
Rye grass - - -	1·00	2·40	12·50	17·70
Timothy - - -	1·10	2·44	16·30	31·97
Pasture grasses - - -	0·75	3·00	10·00	5·00
Hay (meadow) - - -	2·50	10·00	42·00	26·00
Clovers - - -	0·75	3·50	8·00	5·00
Clover hay - - -	2·50	13·00	37·00	25·00

Other leguminous crops and seeds. The important leguminous crops, other than clovers, used as food for animals, are peas, beans, and vetches.

1. **Field peas** (*Pisum arvense*) grow wild in southern European countries. They differ from garden peas (*Pisum sativum*) in colour of flower as well as in size and colour of pea. The flowers of field peas are usually purple; while garden peas are white. Also, field peas, when dry, are brown, grey, or speckled; while garden peas are creamy or bluish.

2. **Field beans** (*Vicia faba*) are varieties of the garden broad bean. The chief kinds grown for farm purposes are horse beans and winter beans. The only important differences between these beans are: winter beans are better able to withstand a low temperature, and are therefore sown in autumn. The beans vary much in colour some being dark brown, others nearly white. Many farmers consider dark-coloured beans richer than those lighter coloured; while others hold the opposite opinion. From analyses carried out by the author, however, there does not appear to be much difference in quality. The following are the average figures obtained on analysis of light- and dark-coloured beans.



FIG. 35.—Bean plant.

Composition of Field Beans.

	Light Colour.	Dark Colour.
	Per cent.	Per cent.
Moisture - - -	13·80	14·05
Oil - - - -	1·95	1·35
Albuminoids - -	21·44	22·50
Carbohydrates - -	51·81	51·00
Fibre - - - -	7·80	7·80
Ash - - - -	3·20	3·30

3. **Vetches or tares** (*Vicia sativa*). The common vetch, or tare, is thought to be a cultivated variety of the wild vetch and belongs to the same genus (*Vicia*) as a field bean. The vetch, however, has more trailing habit than the bean; and the haulm is less woody. Between the kinds grown in England (spring tares and winter tares), little difference can be detected when growing. The winter vetch is hardier than the spring variety, and is less luxuriant in growth. Vetches are usually grown to be used as green food; but occasionally, when weather permits, they are harvested. When this can be successfully carried out, the resultant hay is highly nutritious, especially if cut when just in bloom.

Composition of green tares.

	Per cent.
Oil - - - -	0·4
Albuminoids - -	3·5
Carbohydrates - -	5·5
Insoluble fibre - -	5·0

An analysis of a sample of vetch hay gave the following figures:

Composition of vetch hay.

	Per cent.		Per cent.
Moisture - -	16·39	Carbohydrates -	34·11
Oil - - -	0·79	Insoluble fibre -	33·50
Albuminoids -	6·90	Ash - - -	8·31

Composition of peas and beans.

	Peas (poor quality).	Peas (good quality).	Beans (average quality).
	Per cent.	Per cent.	Per cent.
Oil - - - -	1.40	1.90	1.65
Albuminoids - -	16.25	22.00	23.00
Carbohydrates -	59.36	53.00	51.25
Fibre - - - -	6.10	5.40	7.80

Peas and beans thus prove to be foods fairly rich in albuminoids but deficient in oil. They are used, therefore, to increase the proportion of albuminoids in a mixed ration. The albuminoids consist chiefly of vegetable casein (legumen). In composition, vegetable casein is similar to the casein of milk; hence the use of pea meal in calf foods and beans for milch cows. The old statement "beans for butter" is not far from the truth. Some farmers assert that for milk production a mixture of bean meal and maize meal is as good as oil-seed cakes. Even though this may not be absolutely true, the mixture forms at any rate a remarkably good substitute.

Composition of pea and bean haulm.

	Pea Haulm.	Bean Haulm.
	Per cent.	Per cent.
Oil - - - -	1.2	1.0
Albuminoids - -	9.5	8.3
Carbohydrates -	33.5	32.0
Fibre - - - -	34.2	35.2

From the above table it will be noticed that pea and bean haulm are quite nutritious foods; not equal to clover hay, but approaching good meadow hay. The dried haulm should, however, be fed with care, as some animals are unable to digest them.

Oil seeds. The important oil seeds used in farm practice are linseed, cotton seed, rape seed, earth nut, palm nut, and soya beans.

1. **Linseed.** This is the seed of the flax plant (*Linum usitatissimum*). The plant is grown both for the production of fibre (flax) and for seed. If for fibre the crop is harvested at an earlier stage than if for seed. Ripe linseed is very oily, the oil usually varying between 35 and 40 per cent. Linseed is used directly as a cattle food; but for farm purposes it is generally fed in the form of linseed cake, which is the residue after expression of the greater portion of the oil. Linseed cakes vary greatly in composition, depending upon (1) the seed from which prepared, (2) the extent to which the oil has been extracted.

The chief countries producing linseed are Russia, America, and India. Seed grown in cold countries is said to be richer in oil than that from warmer climates.

2. **Linseed cakes.** The important kinds found on the market are English, Russian, and American. English cakes are those manufactured in England but not from English seed, as linseed is not grown for seed production to any extent in this country. English cakes are prepared from well-cleaned seed; and not being too hard pressed, are rich in oil and albuminoids.

American cakes are clean, but very hard pressed; therefore they are not as rich in oil as English cakes.

Composition of linseed cakes.

	Moisture.	Oil.	Albu- minoids.	Carbo- hydrates.	Fibre.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
English (average)	11.00	9.50	29.50	35.60	9.20	5.2
American - -	10.20	7.00	32.50	37.60	8.20	4.5
Russian - -	12.67	14.25	20.56	33.39	5.35	13.78

Russian cakes, especially those made by peasants, are

soft, due to methods of extraction being primitive compared with those used in England and America, resulting in a cake very rich in oil. Russian seed is, however, very often imperfectly cleaned, weed seeds being frequently present, which is a disadvantage.

3. Cotton seeds. The cotton plant (*Gossypium hirsutum*) is grown largely in Egypt and India; hence the two important seeds found on the market are Egyptian and Bombay seeds. Cotton seeds have a covering of fine cotton or lint, which should be removed before the seeds are used for feeding purposes. If allowed to remain, the cotton has a tendency to accumulate in the intestines of animals, producing inflammatory troubles. The removal of cotton from the seeds is known as "delinting" or "ginning"; and the fine material obtained is known as lint. Seeds when delinted are blackish in colour. The delinted seeds are pressed to extract the oil, which is used in the manufacture of margarine, as salad oil, and for culinary purposes. The residue from whole seeds thus pressed is known as undecorticated cotton cake (that is, cake from seeds undecorticated or unhusked). If the husks are first removed, decorticated cotton cake is the result.

4. Undecorticated or rough cake. This is largely used in England. If prepared from well-ginned seed, and with no addition of extraneous husk, it is quite a safe food to use. Some samples, however, contain excessive husk and others too much lint. The husk contains an astringent principle which checks the tendency to scour, that is, to produce diarrhoea or frequent evacuation, possessed by the decorticated cake.

5. Decorticated cake. This being prepared from husked seed, is richer in oil and albuminoids than the undecorticated cake. Its great disadvantage is its richness. It should always be used with care, as the high proportion

of albuminoids present renders it unsuitable for very young stock. For increasing the albuminoids in a ration, it can scarcely be excelled.

Composition of cotton cakes : average analysis.

	Uncorticated Cake.	Decorticated Cake.
	Per cent.	Per cent.
Moisture - - -	11.50	8.50
Oil - - - -	5.00	9.50
Albuminoids - -	22.50	41.50
Carbohydrates - -	34.50	25.43
Fibre - - - -	20.00	8.25
Ash - - - -	6.50	6.82

6. **Rape seed.** The chief countries producing rape seed are East India, Russia, and China. Rape seed (from *Brassica campestris*) is grown for the production of rape oil. The residue from the presses is known as rape cake. These cakes are liable to contain mustard seed, which is known to produce intestinal trouble in cattle; therefore the cakes are not much used for feeding purposes.

Analysis of rape seed and cake.

	Rape Seed.	Rape Cake.
	Per cent.	Per cent.
Moisture - - -	6.5	8.20
Oil - - - -	24.0	10.50
Albuminoids - -	26.5	29.42
Carbohydrates - -	20.1	31.50
Fibre - - - -	9.8	10.20
Ash - - - -	13.1	10.18

7. **Earth nut.** Earth nuts, pea nuts, or ground nuts are seeds of a leguminous plant, *Arachis hypogea*. The pods are developed underground. They are not nuts, but fruits

(pods) which complete their development below ground ; hence the name ground nut. The oil from the seeds is used largely in cooking, while the residue is consumed as cattle cake. In composition, earth-nut cake approaches that of decorticated cotton cake, some samples even exceeding decorticated cotton cake in percentage of albuminoids.

Analysis of earth-nut cake.

	Per cent.
Moisture - - - -	9.00
Oil - - - -	16.50
Albuminoids - - -	44.25
Carbohydrates - -	21.53
Fibre - - - -	4.20
Ash - - - -	4.52

8. **Palm-kernel cake.** The fruit of the African oil palm (*Elaeis guineensis*) furnishes a very valuable oil known as palm oil (Fig. 36). It is expressed from the outer pulpy coating (pericarp) of the fruit. The pulp encloses a so-called nut, within which is a kernel which is the seed of the palm-tree. The oil expressed from the kernel is sold as palm-kernel oil, and differs chemically and physically from the palm oil obtained from the pericarp. Palm kernels are imported chiefly from West Africa (Sierra Leone, Senegal, Nigeria, and French Congo). Although the trade has been established for about fifty years it is only since 1914 that English traders have taken up the matter, as Germany had until then practically a monopoly of the trade.

The residue after extraction of the palm-kernel oil is compressed into cakes and sold as cattle food. Average samples contain 5 to 10 per cent. oil, 16 to 18 per cent. albuminoids, and 34 to 40 per cent. carbohydrates, the tendency at present being lower oil and higher albuminoids and carbohydrates.

9. **Soya-bean cake and meal.** Soy beans, soya or soja beans, are the seeds of *Glycine hispida*, a leguminous plant cultivated in Japan (Fig. 37). Until 1909 very little was heard of these seeds in England; although in China and Japan they had been known and used as food for years. The seeds have more the appearance of peas



FIG. 36.—Oil palm.

than beans. The oil extracted, soya oil, is brownish in colour and has a tendency to develop a disagreeable flavour not present in the fresh oil. For this reason it does not find favour for culinary purposes unless fresh. The residue after expression of the oil is known as soya-bean cake, which is extremely rich, especially in albuminoids.

Analysis of Soya-bean Cake.

	Per cent.
Oil	7.00
Albuminoids	43.00
Carbohydrates	27.00
Fibre	5.00

Further expression of the oil results in a meal containing a lower proportion of oil, say 2 to 5 per cent., and a corresponding increase in albuminoids.



FIG. 37.—Soya bean.

10. Coco-nut cake. Coco-nuts are the fruits of *Cocos nucifera* (Figs. 38 and 39). There is probably no vegetable product which is so completely made use of by man as the coco-nut. The outer fibrous covering is made into

mats or matting, the husk is burned in the kilns in which the edible portion (copra) is dried. From copra, coco-nut oil is obtained; the residue after extraction being pressed into coco-nut cake. This cake was before 1914 largely used on the Continent, but very little in England. Lately

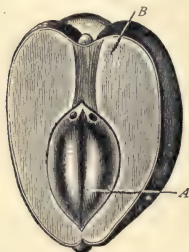


FIG. 38.—Section of coco-nut.

A. Nut. B. Outer fibrous covering.



FIG. 39.—Coco-nuts.

it has been tried, and is now fairly largely used by English farmers. The cakes vary greatly in composition, but the following figures may be taken as average.

Composition of coco-nut cake.

	Per cent.
Moisture - - - - -	11.84
Oil - - - - -	10.00
Albuminoids - - - - -	21.44
Carbohydrates - - - - -	42.20
Insoluble fibre - - - - -	8.15
Ash - - - - -	6.37

QUESTIONS.

1. What are the important constituents in farm foods ? What part does each constituent play in the animal economy ?

2. A cake is sold containing 10 per cent. of oil and 20 per cent. of albuminoids, and the coefficients (that is the percentages digested) for oil and albuminoids are 85 and 82 respectively. Calculate the proportion of oil and albuminoids the animal actually digests.

3. From what seeds, fruits, or nuts are the following prepared : linseed, undecorticated and decorticated cotton, rape, soya, coco-nut, palm nut, ground nut, and compound cakes ?

4. What are the important differences in chemical composition between natural grasses and clovers ?

5. State briefly how (a) the soil, (b) manuring, (c) climate, (d) harvesting and storing, affect the composition of a crop of meadow hay.

6. Leguminous crops are said to be nitrogen conservers. Explain this.

7. Can you suggest any reason why American linseed cakes are hard pressed, while Russian cakes are soft and often very dirty with numerous weed seeds present ? How do these physical characteristics influence (a) the feeding value, (b) the keeping qualities of the seed cakes ?

8. How can a cotton cake (undecorticated) made from Egyptian seed be distinguished from, say, a Bombay cotton cake (undecorticated) ?

9. Why should decorticated cotton cake be fed with care ?

10. Rape cakes have occasionally been known to cause serious intestinal trouble. Suggest a likely cause.

11. Distinguish between amides and albuminoids, and mention foods rich in amides and others rich in albuminoids.

12. Describe the process of haymaking from the time of cutting the grass to storage in the stack, directing particular attention to any climatic or mechanical influences which may affect its final value as a farm food.

13. A crop of linseed cannot be successfully grown both for seed and fibre (flax). Why is this ?

CHAPTER VIII.

FARM FOODS: CEREAL GRAINS, ROOTS, AND GREEN FOODS.

THE chief cereal grains used as food for farm stock are wheat, oats, barley, maize, and rice.

Wheat. This cereal is seldom used as cattle food, being chiefly ground for flour. The various siftings are, however, used largely on the farm. Taking the siftings in order, we have first, flour, then middlings, sharps, pollards, and bran, the last being the coarsest.

Composition of wheat and by-products.

	Wheat.	Flour.	Mid- dlings.	Sharps.	Pollards.	Bran.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture - -	13.56	12.50	12.55	11.59	11.92	12.75
Oil - - -	1.70	1.00	4.55	5.30	5.22	3.95
Albuminoids - -	13.40	12.50	16.63	16.19	17.93	17.93
Carbohydrates -	66.89	73.60	57.03	55.60	54.56	51.96
Fibre - - -	2.66	Trace	5.20	6.26	6.38	8.35
Ash - - -	1.79	0.40	4.04	5.06	3.99	5.06

When a grain of wheat is examined it is seen to be composed of cells of which the outer are filled with nitrogenous substances (albuminoids or proteids), while the inner cells contain starch (Fig. 40). During milling the grain is broken up and the fine starch grains are separated. These grains are ordinary flour. The outer cells (the albuminoid

layer) become also more or less disintegrated and appear chiefly in the middlings, sharps, pollards, and bran. These by-products are, therefore, richer in nitrogen than either the flour or the original grain.

The by-products are used as cattle and poultry food. Bran is especially useful, being a gentle laxative and containing much



FIG. 40.—Longitudinal and transverse sections of wheat (multiplied 10 diameters).

- a. Bran.
- b. Endosperm.
- c. Germ.
- d. Secretory epithelium.
- e. Scutellum.

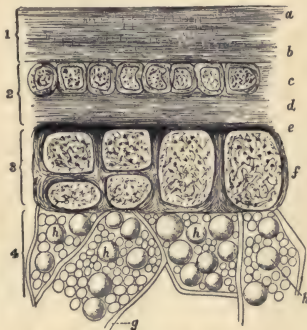


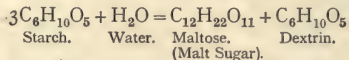
FIG. 41.—Section of bran (magnified).

- 1. External coat—*a*, epidermis; *b*, epicarp.
- 2. Middle coat—*c*, endocarp; *d*, episperm.
- 3. Internal coat—*e*, membrane; *f*, cereal in cells.
- 4. Endosperm—*g*, wall of cellulose cell; *h*, starch grains.

phosphate of lime in the ash. Two kinds of bran are always found on the market—namely, coarse and fine bran; or, as they are often called, broad bran and bran. Chemically there is little difference between them, it being more a question of size than composition. (Fig. 41.)

Barley, barley meal, and brewers' grains. Barley (or, when ground, barley meal) is a rather starchy grain,

and as such is seldom fed alone except to pigs. Pigs are said to possess the power of converting starch into fat. Barley when malted (that is, moistened and allowed to sprout) alters materially in composition, the starch being changed to sugar. The substance bringing about this change is a ferment known as **diastase**. Without moisture and warmth, diastase is inactive: but when these two conditions are satisfied, the change from starch to sugar takes place rapidly according to the following equation:



When sugar is treated with yeast, alcohol and carbon dioxide are produced. Thus, by malting barley and acting upon the resulting sugar with yeast, various forms of beer are manufactured.

The barley grains after being thus used are sold for feeding purposes as wet brewers' grains, or, if dried, as dried grains.

The quality of the water used for brewery purposes affects somewhat the composition of the resultant grains. Hard water (that is, water which requires much soap to produce a lather) extracts very little of the albuminous matter from the grains. Soft water has much more effect; hence the reason why grains vary somewhat in composition. The albuminoids extracted are known as soluble albuminoids. Brewers' grains are, therefore, deficient in soluble albumen. But soluble albumen is not as valuable as insoluble albumen for flesh production; hence the remaining insoluble albumen has a high value for feeding purposes. Wet grains are much used for producing a large flow of milk; but if stored for any length of time before use they are apt to become sour, and, when so, there is a tendency to produce a disagreeable flavour in the milk.

The sprouts produced when barley is malted are collected and sold for feeding purposes as *malt coombs* or *comblings*; they are a rich food and excellent for milk production.

Composition of barley meal, wet grains, dried grains, and malt coombs.

	Barley Meal.	Wet Grains.	Dried Grains.	Malt Coombs.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture - - -	10.75	74.32	8.30	17.00
Oil - - - -	2.60	2.01	8.87	4.00
Albuminoids - -	11.12	3.90	17.95	23.18
Carbohydrates -	63.63	13.67	44.98	42.22
Fibre - - - -	8.40	4.85	16.50	8.50
Ash - - - -	3.50	1.25	0.40	5.10

Oats. The nutrients of oats are nicely balanced; that is, the oil, albuminoids, and carbohydrates are in satisfactory proportion for feeding purposes. Oats, however, vary much in composition, due to differences in the proportion of the husk and grain. They are excellent food for horses; because the horse, having a small

Composition of ground oats and oat meal.

	Ground Oats.	Oat Meal.
	Per cent.	Per cent.
Moisture - - -	10.73	11.75
Oil - - - -	5.12	8.10
Albuminoids - -	11.15	15.00
Carbohydrates -	61.24	59.25
Fibre - - - -	8.10	3.20
Ash - - - -	3.66	2.70

stomach, requires feeding with a fairly concentrated food which requires a minimum of energy for digestion. Again, a horse is fed for the production of energy; therefore the

less the expenditure on digestion, the more there remains for work. Ground oats are greatly in favour with poultry fatteners. In Sussex and Surrey, where fowls are fed artificially for table purposes, ground oats form the basis of the diet provided. Oat meal differs from ground oats in composition. Ground oats are whole oats ground to a fine meal, but oat meal is the ground husked oat.

Maize. Maize, or *Indian corn*, is the most starchy food used on the farm. The seeds are extremely hard and should always be crushed (or kibbled) before being fed. *Maize meal* is the ground whole grain, *maize germ* consists of the germ plus some starchy matter. *Corn flour* is the starch obtained from maize. *Maize gluten feed* consists of the residue after removal of the starch; while *maize gluten meal* is generally devoid of husk and germ. These names are not, however, of much importance as an index to the feeding value, as manufacturers do not appear to be unanimous in their nomenclature of maize by-products.

It is not advisable to use maize or maize products alone; but when properly mixed with other foods they are extremely useful.

Composition of maize and gluten feed.

	Maize.	Gluten Feed.
	Per cent.	Per cent.
Moisture - - -	10.85	12.76
Oil - - - -	5.83	5.29
Albuminoids - -	11.81	20.12
Carbohydrates -	62.59	57.83
Fibre - - - -	5.72	3.10
Ash - - - -	3.20	0.90

Rice. Rice is largely obtained from India, Burma, Java, and the United States and Egypt. When growing, it appears somewhat similar to oats. The threshed grain

is known as **paddy**. After removal of the husk or hull, the grain is subjected to various milling processes, which remove the outer coating or cuticle of the grain as well as the germ.

Rice grain when ready for market consists of little but starch, the outer nitrogenous cells having been removed by milling. The grains are then sifted into head rice (intact grains) and tail rice, the tail rice being then graded according to size into "smalls" and "points." Rice meal consists of the finest siftings collected during the whole process of milling. Table rice is usually polished by shaking the grains with talc or French chalk, or occasionally with oil.

Rice used for poultry feeding consists chiefly of broken grain (smalls); while the meal mentioned above is used either alone or as a constituent of compound cakes.

Rice meal varies greatly in composition, depending upon the extent to which the outer oil and nitrogenous cells (bran) are included in or excluded from the meal.

Composition of rice meal.

	1	2	3
	Per cent.	Per cent.	Per cent.
Moisture - - -	11.01	9.22	8.75
Oil - - -	2.34	17.20	14.25
Albuminoids - -	8.31	12.30	13.12
Carbohydrates -	76.69	48.11	51.88
Fibre - - -	0.38	3.90	3.00
Ash - - -	1.27	9.27	9.00

Sample 1 consisted largely of ground rice with very little rice bran present; hence the low oil and albuminoids. Samples 2 and 3 are genuine meals. It is not unusual to find ground rice husk or hulls in the meal. The hulls have an irritant effect upon the stomach and intestines

of animals, and they should not be included in any feeding mixture. The subjoined Table shows the values obtained on analysis of rice hulls and a rice meal adulterated with husk.

Composition of rice hulls and adulterated rice meal.

	Rice Hulls.	Rice Meal adulterated with Husk.
	Per cent.	Per cent.
Moisture - - -	10.40	7.98
Oil - - - -	1.46	6.37
Albuminoids - -	7.00	10.06
Carbohydrates -	36.25	39.92
Fibre - - - -	28.72	16.70
Ash - - - -	*16.17	†18.97

* Including sand, 14.47. . † Including sand, 14.00

Roots, cabbages, and rape. Roots, cabbages, and rape consist largely of water, as shown by the subjoined Table :

Solid matter and water in roots, cabbages, and rape.

Roots.	Solid matter.	Water present.
	Per cent.	Per cent.
Turnips - - -	9.5	90.5
Swedes - - -	11.5	88.5
Mangolds - -	12.0	88.0
Carrots - - -	13.0	87.0
Sugar beet - -	25.0	75.0
Potatoes - - -	25.0	75.0
Cabbages - - -	15.0	85.0
Rape - - - -	14.0	86.0

The solid matter in the roots consists chiefly of carbohydrates. Oil is practically absent, while albuminoids in no case exceed 2.75 per cent. As compared with other

foods, roots are remarkably low in oil, albuminoids, and carbohydrates. This is well seen by placing the analysis of a linseed cake against the average figures obtained on analysis of the above roots, etc.

Comparative analyses of linseed cake, roots, cabbages, and rape, etc.

	Linseed Cake.	Turnips.	Swedes.	Mangolds.	Carrots.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Oil - - - -	9.5	0.25	0.25	0.25	0.25
Albuminoids - -	29.5	1.00	1.25	1.25	1.25
Carbohydrates - -	35.6	6.00	8.00	9.00	9.50
Fibre - - - -	9.2	1.00	1.50	1.00	1.50

	Sugar Beet.	Potatoes.	Cabbages.	Rape.
	Per cent.	Per cent.	Per cent.	Per cent.
Oil - - - -	0.25	0.25	0.75	0.75
Albuminoids - -	1.25	2.00	2.50	2.75
Carbohydrates - -	20.00	21.00	7.00	6.00
Fibre - - - -	2.00	1.00	2.00	3.00

The above constituents are not entirely digested by animals, but when mixed with other foods they are usually considered to be digested with fair completeness. Containing such high percentages of water, roots and cabbages must be fed in reasonable quantities. The temperature of the water present has to be raised to that of the body by the heat produced by combustion of the carbohydrates; therefore, if fed in excess, there is consequent waste of food. Again, very watery food affects the digestion, as too great dilution of the contents of the stomach may result in the inability of the gastric juice to perform its normal functions; hence indigestion may follow.

Compound cakes and meals. Under this head may be included cakes or meal which consist of more than one

substance or seed. Many of these mixtures are very valuable; others are certainly not worth the price charged for them. The cakes have generally a linseed or cotton-seed basis, the remainder being anything except poisonous seeds. The only safeguard against purchasing worthless compound cakes is, first, to see they are guaranteed; secondly, to have them examined in order to ascertain if the guarantee is correct; and thirdly, to test them as to feeding or milk-producing value in comparison with standard cakes like linseed and cotton seed. Compound meals and cakes are generally flavoured with such spices as fenugreek, aniseed, gentian or caraway. The spices add nothing to their feeding value, but by making the compound cake more palatable cause more to be taken.

Various names are applied to these compound feeding stuffs. Feeding cake, fattening cake, dairy cake, calf meal, pig meal, are all names pointing to some specific purpose for which they are intended. It is only fair to state they are generally serviceable for the purpose in view; but one important question should always be answered before deciding to use them regularly, and that is: Are they as good and cheaper than the standard cakes, such as linseed cake and cotton cake? If not, then nothing can be gained by their use.

Composition of various compound cakes and meals.

	Fattening Cake.	Rearing Cake.	Dairy Meal.	Dairy Cake.	Pig Meal.	Calf Meal.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture - -	13·80	13·20	9·85	11·20	14·30	12·68
Oil - - -	10·50	9·50	9·55	8·10	2·25	7·65
Albuminoids -	21·43	20·56	14·87	19·25	11·81	15·75
Carbohydrates -	38·65	43·72	48·48	45·03	74·46	54·48
Fibre - - -	7·60	5·90	8·83	10·10	4·70	4·90
Ash - - -	8·02	7·12	8·42	6·32	2·48	4·54

FARM FOODS: DIGESTIBILITY AND MANURIAL VALUE.

Digestibility. The chemical analysis of foods is carried out for the purpose of ascertaining the nutrients present, and also to detect the presence of foreign, deleterious, and worthless ingredients. Quantitatively, such analyses leave nothing to be desired, but they give no information concerning the important quality of digestibility. A food may be quite rich when considered chemically, but if the constituents cannot be digested easily by animals, the value of that food is materially lowered.

Digestibility experiments have been carried out, and results have been obtained showing the percentage digested by various animals; but as the digestive powers of animals of the same breed are not equal, only average figures can be given, and these in exceptional cases must be very wide of the mark. The subject bristles with difficulties, and it is only within the last few years that what may be called scientific feeding, based on digestibility experiments, has been practised with any success.

It is, however, upon the proportion digested that the farmer has to depend for the production of energy, meat, and milk; the undigested food is excreted and has value only as manure.

Digestion. Digestion is a physiological process which is at present very imperfectly understood, but the general results may be briefly stated as follows. Of the important food constituents (oil, albuminoids, and carbohydrates), oil can be directly laid on as fat, and may be oxidized to produce heat. Carbohydrates are generally used as a source of heat, and are capable of producing just as much heat in the animal system as they would if burned. Thus, we speak of the calorific value of a food, just as we do that

of a fuel ; in fact, carbohydrates may be looked upon as animal fuel. If the carbohydrates are of the nature of sugar they may undergo combustion directly, but if of a starchy nature, they must first undergo a change into sugar. Starch is insoluble, and as such cannot enter the blood stream ; but sugar is soluble and can be directly absorbed. Albumen is insoluble ; therefore, before absorption, it must be rendered soluble. This change is brought about by a ferment known as **pepsin**, which changes insoluble albumen into soluble peptones, or albumoses.

If food is traced from the commencement of mastication until digestion is completed, it is found that the following changes take place. During mastication the food is mixed with saliva from the salivary glands of the mouth. Saliva contains a small proportion of diastatic ferment ; and therefore, the starch of the food is to some extent changed to sugar.

On reaching the stomach the food is acted upon by the gastric juice. This stomach secretion is always acid. Its specific gravity lies between 1.00 and 1.010 ; it contains the important ferment pepsin, which is capable of changing insoluble albumen (true albumen) into soluble albumen, thus rendering it capable of diffusion and absorption.

In addition to pepsin, gastric juice contains another ferment, **rennet**, which has the power of curdling milk, as well as a third called **lipase**, which decomposes fats into glycerine and fatty acids.

After leaving the stomach the partly digested food is attacked by two digestive juices derived from the pancreas and liver. These are known as **pancreatic juice** and **bile**. Pancreatic juice contains three ferments, one of which is known as **trypsin**, which brings about further changes in the proteids or albumen ; while another ferment acts upon fats, and a third upon starch. The bile also assists by

acting upon fatty matter. Following these changes, the juices of the intestines come into play and complete the work of digestion already well advanced by the ferments.

In addition to the above changes undergone by the food, there is also the action of various types of bacteria, the work of which, though important, has not at present been fully investigated.

The indigestible matter, that is, the portion not rendered soluble by the digestive juices, is excreted, along with the waste products incidental to vital activity.

Digestibility coefficients. By experimenting upon animals it has been found that, with foods of average quality, and animals possessing average digestive powers,

Important digestibility coefficients (Wolff).

	Albuminoids.	Oil.	Carbohydrates.	Fibre.
	Per cent.	Per cent.	Per cent.	Per cent.
Pasture grass -	72 to 79	63 to 69	75 to 84	72 to 80
Meadow hay -	42 „ 72	10 „ 63	49 „ 76	46 „ 71
Clover hay -	55 „ 69	44 „ 72	67 „ 72	39 „ 52
Oat straw -	14 „ 48	20 „ 49	39 „ 45	48 „ 64
Oats -	68 „ 86	75 „ 92	67 „ 88	0 „ 44
Maize -	60 „ 79	82 „ 89	91 „ 96	62 „ 100
Beans -	88 „	86 „	93 „	72 „
Peas -	89 „	75 „	93 „	66 „
Linseed cake -	84 „ 87	89 „ 96	70 „ 91	26 „ 62
Palm-nut cake -	89 „ 100	89 „ 100	92 „ 96	72 „ 92
Earth-nut cake	91 „	86 „	98 „	16 „
Cotton cake } (dec.) }	85 „	88 „	95 „	0 „
Mangolds -	66 „ 86	—	94 „ 96	—
Turnips -	57 „	—	89 „	—

the percentage digested is fairly uniform. Tables have been drawn up setting forth the percentage digested. The figures are known as digestibility coefficients, and are

used as follows. Suppose a linseed cake on analysis proves to contain 10 per cent. oil and 30 per cent. of albuminoids, and the digestibility coefficients for oil and albuminoids in linseed cake to be 96 and 82 respectively; then 96 per cent of 10, that is, 9.6, is the actual amount of the 10 per cent. of oil digested; and 82 per cent. of $30 = 24.6$; that is, 24.6 of the 30 per cent. of albuminoids are actually digested.

It should specially be noted that in any feeding experiments the percentage digested is considered always and not the actual percentage present. Failure to appreciate this may lead to serious errors.

Rations. Food is supplied to animals for three purposes, namely, (1) to repair tissue waste, (2) to produce flesh and fat, (3) for the production of energy. The amount required to accomplish the first result is known as the *maintenance diet*; that is to say, it will just keep the animal in store condition, and no more. Any excess over the maintenance diet may be either excreted, laid on as flesh or fat, or used for the production of energy. In the compounding of any rations for farm animals, the above considerations have to be kept in view.

It is beyond the scope of this book to consider the subject in detail, but a table showing the requirement of a dairy cow and a specimen ration satisfying such requirements will illustrate the method of work.

Animal.	Digestible Fat required.	Digestible Albu- minoids required.	Digestible Carbo- hydrates required.
Cow in milk (giving 1 gallon) -	0.3 lb.	1.5 lb.	9.0 lb.
" " (each extra gallon pro- duced) - - - }	0.2 "	0.6 "	2.8 "

Comparative valuation of farm foods. Whenever two quantities are compared, or their comparative values ascertained, a unit with which the comparison is made must be decided upon. When the area of a field is stated, a number is given which indicates how many times that field is larger than a standard area (1 acre). If a length is noted, it is expressed in terms of a yard, a foot, an inch, or similar unit; while the volume of milk produced by a cow is stated as a multiple of a unit volume, 1 gallon, 1 quart, or 1 pint.

In valuing foods the unit taken is 1 per cent. of any carbohydrate. As oil and albuminoids have about two and a half (2.5) times the value of carbohydrates for feeding purposes, they must be multiplied by this figure to convert them into food units. An example will make this much clearer than further description. On analysis, a cake gives, say, the following values :

Oil - - - - -	10 per cent.
Albuminoids - - - - -	20 „
Carbohydrates - - - - -	40 „

It is required to ascertain the food units present, taking 1 per cent. carbohydrates as the standard unit.

Carbohydrates	40 per cent.	-	-	= 40 units.
Oil (× 2.5)	10	„	-	= 25 units.
Albuminoids (× 2.5)	20	„	-	= 50 units.
Total food units	-	-	-	115

The cake, therefore, contains 115 food units. Using this simple method, it is possible to compare farm foods with a reasonable amount of accuracy, not only with reference to the number of food units they contain, but also with regard to the cost of each unit, provided the price per ton is known.

If two concentrated foods, say linseed cake and undecorticated cotton cake, are offered as follows, the method described above can be applied.

Undecorticated cotton cake at £6 per ton containing 5 per cent. oil, 22 albs., 38 carbs.

Linseed cake at £9 per ton containing 9 per cent. oil, 24 albs., 38 carbs.

Food units present in linseed cake - - - = 38 and $(9 + 24) 2\frac{1}{2} = 120.5$

Food units present in undec. cotton cake - - - = 34 and $(5 + 22) 2\frac{1}{2} = 101.5$

Value of 1 unit linseed cake $\frac{£9}{120.5} = \text{rs. } 5\frac{3}{4}\text{d.}$

Value of 1 unit undec. cotton cake $\frac{£6}{101.5} = \text{rs. } 2\text{d.}$

The above valuation by food units is made on the assumption that both are digestible to the same extent; also that the albuminoids, oil, and carbohydrates have in both cakes the same relative value. Such is not quite true, but the method is the simplest at present known for comparing directly the feeding values of farm foods.

Starch equivalents. Another method of comparing foods, which is much more complicated than by food unit, is known as the **starch equivalent system**. By direct experiments on animals it has been found that 100 lbs. of starch will produce 25 lbs. of fat. If, therefore, 100 lbs. of meadow hay will under similar condition produce 8 lbs. of fat, its starch equivalent must be 32. The starch equivalents of most of the ordinary farm foods of average composition have been ascertained; thus these foods can be arranged in ascending or descending order of their starch equivalents.

This method, worked out so adequately by Kellner and recorded in his book, *The Scientific Feeding of Animals*,

has, however, certain drawbacks which cannot be overlooked; and it fails to give starch values of the coarse fodders directly comparable with the more concentrated foods. Deductions have to be made, and as these vary with the proportion of insoluble fibre present, while the insoluble fibre varies in the same kind of food, the calculation becomes somewhat complicated; therefore, for general use, the food unit system is usually applied.

For the present it may be said that the simplest method of ascertaining the cheapest food on the market is by the food unit system; but when the question of feeding is approached, the use of starch equivalents becomes a necessity.

The scientific feeding of animals is, however, much too abstruse for an elementary work. Students desiring to go deeper into the subject would do well to read Wolff's *Farm Foods* (Gurney & Jackson), or Kellner's *Scientific Feeding* (Duckworth & Co.), and Henry's *Foods and Feeding*.

Manurial values. If animals are supplied with a maintenance diet only (that is, with just enough food to keep them in condition without increase or decrease in weight) the manurial value of the excreta dung and urine is practically equal to that of the food supplied. The excretions, however, are subject to loss immediately they are voided. Experiments have been carried out in order to ascertain the extent of the said losses, and tables have been drawn up showing the value of the manure obtained from every ton of food used. It has been found that of the total nitrogen, phosphates, and potash which enter the animal as food, one-half of the nitrogen, three-quarters of the phosphoric acid, and the whole of the potash, are returned in the dung. Allowing 12s. for each 1 per cent. nitrogen, 3s. for phosphoric acid, and 4s. for

potash, the following figures are obtained for the foods generally used on farms :

Composition in respect of Manurial Ingredients and the Manurial Value of Various Farm Foods.

Food.	Percentages.			Estimated Value per ton.
	Nitrogen.	Phosphoric Acid.	Potash.	
	Per cent.	Per cent.	Per cent.	£ s. d.
Decorticated cotton cake *	6.9	3.1	1.6	2 14 10
Undecorticated „	3.6	2.5	1.6	1 13 7
Linseed cake - - -	4.7	1.7	1.3	1 17 3
Earth-nut Cake - - -	7.5	1.3	1.5	2 14 0
Coco-nut cake - - -	3.4	1.5	2.0	1 11 10
Palm-nut cake - - -	2.6	1.1	0.5	1 0 1
Soya bean cake - - -	6.9	2.2	1.8	2 13 6
Middlings - - - -	2.4	1.4	0.8	1 0 9
Sharps - - - - -	2.5	2.6	1.4	1 6 6
Bran - - - - -	2.4	2.7	1.5	1 6 6
Gluten meal - - -	6.1	0.3	0.05	1 17 6
Gluten feed - - -	4.2	0.7	0.2	1 7 7
Rice meal - - - -	1.9	2.5	0.7	0 19 10
Wet brewers' grains -	0.85	0.4	0.05	0 6 2
Dried „ „ - - -	3.3	1.6	0.2	1 4 2
Wheat - - - - -	1.8	0.9	0.6	0 15 2
Oats - - - - -	1.9	0.7	0.5	0 15 0
Maize - - - - -	1.7	0.6	0.4	0 13 2
Beans - - - - -	4.0	1.2	1.3	1 11 11
Wheat straw - - -	0.45	0.2	0.8	0 6 4
Oat „ - - - - -	0.5	0.2	1.5	0 9 6
Meadow hay - - -	1.5	0.4	1.6	0 16 4
Clover „ - - - -	2.2	0.6	1.8	1 1 8
Pasture grass - - -	0.5	0.15	0.6	0 5 9
Cabbage - - - - -	0.4	0.15	0.4	0 4 4
Rape - - - - -	0.45	0.15	0.3	0 4 3
Swedes - - - - -	0.2	0.1	0.3	0 2 8
Mangels - - - - -	0.2	0.1	0.5	0 3 5

* As explained, half of 6.9 per cent. nitrogen, multiply by 12s.; add three-quarters of 3.1 per cent. of phosphoric acid, multiply by 3s.; add 1.6 per cent. potash, multiply by 4s., equals £2 14s. 10d.

This table is of great value to farmers interested in stock feeding. To give one elementary example. Suppose by experiment it has been found that earth-nut cake gives as good results in a ration as undecorticated cotton cake, and that the prices are approximately the same. The manurial value of undecorticated cake is £1 13s. 7d. for each ton used, while the residue from earth-nut cake is valued at £2 14s. Od., practically £1 greater for every ton used. Obviously, if the two have the same feeding value and are the same price, it would be more economical to use the earth-nut cake, seeing there is a gain of £1 on the manurial residue of each ton.

To put the matter very briefly, the feeding of animals should never be undertaken without taking into consideration the value of the manure produced during feeding, because in some cases it is to the value of the manure that the feeder has to look for profit, especially when, on account of market fluctuations, he has been compelled to buy store stock at a high figure and to sell the finished animal at a price which shows a very small margin of profit.

QUESTIONS.

1. Mention the important by-products obtained in the milling of wheat. How do they differ from each other in composition, and from the flour obtained, and from the original wheat?

2. What are dried grains, wet grains, and malt culms or coombs? How do they compare as regards (a) oil, and (b) albuminoids?

3. What are ground oats and oat meal? Why is oat meal a richer food than ground oats?

4. How would you prove that maize is a very starchy food? Mention any farm foods you would mix with maize to improve its value as a feeding stuff.

5. Mention a common adulterant of rice meal, and state briefly how you would detect the presence of the adulterant named.

6. Would you give an animal as much water when allowing, say, 50 lbs. of roots per day, as when feeding on hay and plus concentrated food but no roots? Why?

7. Classify roots according to the percentage of water they contain.

8. What is a compound cake? State clearly what adulterants you would specially look for in compound cakes and meals.

9. What advantage is gained by slightly warming food or taking the chill off water before giving it to an animal?

10. Which contains most water, 100 lbs. of milk or 100 lbs. of mangolds?

11. Arrange all the farm foods with which you are acquainted in the order of percentage of albuminoids present. Do the same, taking oil as a basis.

12. State briefly what you understand by digestible and undigestible matter.

13. What are coefficients of digestibility, and of what use is a knowledge of these to stock keepers?

14. If in the feeding of any animal the quantity given is only considered, and no notice is taken of the ratio of the constituent, the result may be disappointing. Explain this.

15. What are food units? Calculate the food units in a cake containing 8 per cent. oil, 22 per cent. albuminoids, and 42 per cent. carbohydrates. If the cake costs £8 per ton, find the unit value.

16. What is meant by starch equivalent?

17. Write a brief description of what is understood by the manurial values of farm foods.

18. When feeding for milk with a cake which costs £10 per ton, and the manurial value of which is £2 per ton, state how much of the £10 should be charged against the milk.

19. Define clearly what is meant by the manurial value of a food.

CHAPTER IX.

MILK AND CREAM.

PRACTICAL WORK.

1. FIND the specific gravity of milk by means of the specific gravity bottle, the hydrostatic balance, and a milk hydrometer (lactometer). Do the same, using skim milk and separated milk. (Figs. 43, 44 and 45.)

2. Weigh out 5 grams of milk in a flat-bottomed porcelain basin. Heat the milk 3 hours on the water oven and 3 hours in the oven. Transfer it to a desiccator and weigh when cold. Return it to the oven for an extra half hour and weigh it again. If the weight is constant, the loss is water, and the residue in the dish the total solids of milk. Calculate the percentage. Repeat with skim milk and separated milk.

3. Ignite the total solids carefully at a dull red heat until no black carbon particles remain. Cool the residue and weigh it again. The residue is the ash of milk. Calculate the percentage.

The following experiment should not be carried out by junior students; and by seniors only when under supervision, as ether is dangerous to work with.

4. Weigh out about 10 grams of milk; heat it on the water oven, stirring often, until the mass is pasty. *Now give your whole attention to it*; keep the solid matter stirred until dry, when it should be crumb-like. Pour 10 to 20 c.c. of ether over the solids, and, by means of the stirrer, bring the ether into intimate contact with every

particle of milk solids. Filter the ether solution into a tared flask.

Repeat the operation five times ; wash the filter paper with a few c.c. of ether. Evaporate the ethereal solution and weigh the residue, which is milk fat. Calculate the percentage.

5. Examine samples of milk and colostrum, or first milk produced after calving, under the microscope, noting any differences. Make drawings to illustrate the important differences.

6. Test samples of milk for fat by the Gerber method as follows :

Obtain two Gerber bottles known as butyrometers. These are graduated on the stem, the graduations representing percentages of fat. Run in 10 c.c. of sulphuric acid (sp. gravity 1.825) ; then 11 c.c. of the milk, followed by 1 c.c. of amyl alcohol. Close the bottle with a rubber cork ; cover it with a duster to prevent accident in case the bottle breaks, and to protect fingers from the heat developed, and shake it vigorously, allowing the acid to run from the narrow stem after each shaking. Repeat the operation three times ; then place the bottles in a centrifugal machine and whirl for from 3 to 5 minutes at from 2 to 3000 revolutions per minute. Remove the bottles and read off the percentage of fat directly. If done correctly, both bottles should read the same value.

Skim milk, separated milk, and thin cream may be tested in a similar manner, special bottles being used for the purpose.

7. Add about 0.1 gram of boric acid to 100 c.c. of milk. Measure out 5 c.c. of the milk ; dry it on the water oven, then char it thoroughly. Add about 2 c.c. of dilute hydrochloric acid ; then dip into the solution a piece of turmeric paper. Allow it to remain there 15 minutes. Dry the paper. Note the brown colour. Touch with caustic soda solution and note the change from brown to blue or bluish black.

Test the original sample containing no boric acid. State whether it colours the turmeric paper.

Now use borax in place of boric acid. State whether the result of the test is the same.

8. Place in a test-tube about 5 c.c. of milk to which one drop of formalin has been added. Add 5 c.c. of water; shake the mixture; then pour down the side of the tube about 3 c.c. of strong sulphuric acid. Note the violet colour produced. Test the original sample in a similar way, and note that the violet colour is not produced.

9. Find the sp. gravity of a sample of thin cream by the method described under milk.

The sp. gravity of thick cream cannot be found directly by ordinary methods. Mix equal proportions of skim milk and cream, then find the sp. gravity of the mixture.

Calculate the sp. gravity of the cream by either of the following formulae.

$M = \text{Sp. gravity of mixture.}$

$S = \quad \quad \quad \text{skim milk.}$

$C = \quad \quad \quad \text{cream.}$

$$2M - S = C, \text{ or, more accurately, } C = \frac{S \times M}{2S - M}.$$

(approximate)

10. Weigh out 5 grams of cream in a flat-bottomed porcelain basin. Heat in an air oven at 100° to 105° till the fat is melted. Tip the dish to expose the solids not fat to the hot air. Weigh and reheat until constant in weight. Loss = water. Multiply loss by 20, which gives the percentage.

11. Dissolve the fat by treating with successive portions of ether. **(Be careful not to use ether near a naked flame.)** Pour off the ethereal solution each time. Dry the residue first in air, then in the water oven till constant. This weight, minus the weight of the dish, gives the solids not fat. Add together solids not fat, and water, and subtract from 100. The difference is per cent. of fat.

12. Boric acid and formalin are tested for exactly as in milk, but before testing for formalin it is advisable to add an equal bulk of skim milk and then test the mixture.

Milk and milk products. Milk is the product of the mammary glands of females, and the name **mammal** is given to any animal possessing mammary glands. Milk from all females has qualitatively the same chemical composition, but quantitatively there are very wide differences. That is to say, from whatever source milk is drawn it contains water, fat, protein, sugar (milk), and ash, but the proportion in which these constituents are present varies not only in different breeds of animals, but in different animals of the same breed.

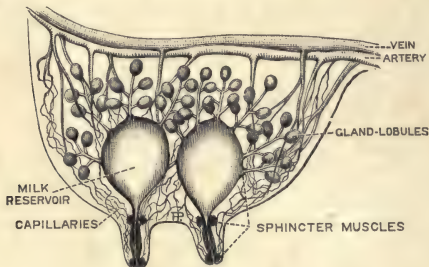


FIG. 42.—Section of cow's udder.

In this book the word milk will be used to indicate cows' milk, unless the milk of other animals is specifically mentioned. In addition to milk, various milk products will be considered, namely: skim and separated milk, cream, butter, butter milk, cheese, and whey.

Milk production. When the udder of a cow is dissected, it is found to consist of two portions separated by a muscular partition running lengthwise. The actual portion of the udder producing milk consists of small **sacs** or **alveoli** lined with **epithelial cells**. The sacs are surrounded by blood-vessels which supply them with the necessary constituents for milk production. Adjacent

to the blood-vessels are nerves which regulate the action of the milk-producing cells. Exactly how milk is formed is not definitely known. So far as can be ascertained, it appears to be the result of the breaking down of the epithelial cells forming the sacs, which cells are rebuilt and again disintegrated. The product, milk, is conducted from the alveoli by **capillaries** which lead into wider channels known as **milk ducts**. The ducts open into a space known as the milk reservoir, and this communicates with the exterior by the **teat** (Fig. 42).

Physical properties of milk. Colour. When freshly drawn, milk has a bluish or yellowish tinge. The yellowish colour appears to be present in the fat. The bluish tinge does not appear to be due to any colouring matter but to the obstruction to the passage of light caused by the proteids of milk not being actually in solution, but in a state of false solution known as colloidal.

Different breeds of cows give milk of different colour. Jersey milk is noted for its yellow or creamy colour, while Ayrshire milk has more of the bluish tinge. The colour of milk is some index to its quality as regards fat, hence the practice so prevalent at present of adding yellow colouring substances to poor milk.

1. **Smell.** Cows' milk has a smell which partakes largely of the animal, but other abnormal odours are often present due to the foods used, or to the absorption of any odoriferous gases present in contact with the milk. The gases usually present in milk are those of the air, namely, oxygen, nitrogen, and carbon dioxide, CO_2 . The proportion in which these are present alters as the milk is kept, the oxygen disappearing while the carbon dioxide increases.

2. **Reaction.** Milk is peculiar in possessing what is known as an **amphoteric reaction**, that is, it turns blue litmus slightly red and red litmus slightly blue. This is due to the

presence of acid phosphates which attack blue alkaline litmus (the alkali being withdrawn), thus producing slightly red litmus. Red litmus, or acid litmus, abstracts alkali from milk, forming slightly blue litmus.



FIG. 43.—Specific gravity bottle.

3. **Specific gravity.** The specific gravity of normal milk varies between 1.029 and 1.032. The first milk (**colostrum**) produced after calving has a much higher specific gravity, varying between 1.045 and 1.079. In each case the specific gravity is found by comparison with water at 15.5° C. (Figs. 43, 44, 45).

Chemical composition of milk. The important constituents of milk are classified as fat, solids not fat, and water. Average milk contains well over 3 per

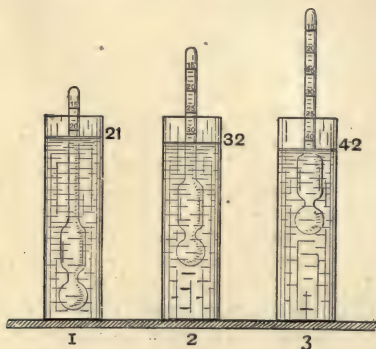
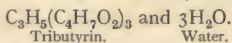
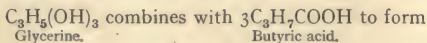


FIG. 44.—Lactometers reading 1.021, 1.032 and 1.042.

cent. of fat and 8.5 per cent. of solids not fat. The fat of milk has characteristics which distinguish it from other fats

and oils. All fats are glycerides of fatty acids, that is, they consist of glycerine, $C_3H_5(OH)_3$, combined with certain fatty acids. The important fatty acids found in milk are butyric, caproic, caprylic, capric (which are volatile), and myristic, palmitic, stearic, arachic, lauric and oleic (which are non-volatile). The chemistry of milk fat is much too complex for an elementary work, but in order to illustrate the composition of fat the formula for the glyceride of butyric acid is given.

One molecule of glycerine combines with three molecules of butyric acid to form tributyrin.



So far as can be ascertained, milk fat does not consist of simple glycerides like tributyrin, but contains in each molecule of fat three distinct fatty acid radicles, instead of three similar radicles.

The important chemical characteristic of milk fat is the presence of volatile fatty acids. This fact is made the basis of an important test for milk fat, that is, the estimation of the volatile fatty acids.

The solids other than fat consist of casein, albumin, lactoglobulin, milk sugar (lactose), and ash.

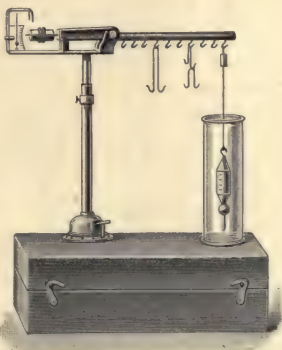


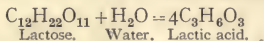
FIG. 45.—Hydrostatic balance.

1. **Casein.** This nitrogenous compound is present in milk in suspension. It can be separated, therefore, by passing milk through a porcelain filter. Its chief characteristics are its power to curdle on the addition of a ferment known as rennet, and the presence of phosphorus in its molecule. It contains practically 16 per cent. of nitrogen, and nearly 1 per cent. of phosphorus. Casein is present in milk to the extent of about 3.5 per cent.

2. **Albumin.** This compound also contains about 16 per cent. of nitrogen but **no** phosphorus. The percentage present is approximately 0.55 per cent.

3. **Lacto-globulin.** This is present in traces only, so need not be considered further.

4. **Milk sugar, or lactose,** $C_{12}H_{22}O_{11}$, H_2O . This sugar is found only in milk. When acted upon by certain organisms (*Bacillus acidi lactici*), the milk sugar is changed to lactic acid, as shown by the following equation :



The formation of this acid in milk causes the ordinary 'souring' of milk. As acids precipitate casein, milk which has soured is curdled (or has the casein precipitated) at the same time.

One notable feature of milk sugar is that it is not fermented by ordinary yeast, with the production of alcohol and carbon dioxide. Yeasts are, however, known which will ferment lactose. These are made use of in the preparation of fermented cows' milk (kephir) and fermented mares' milk (koumiss). Lactose is present in normal milk to the extent of about 4.5 per cent.

5. **Ash.** The ash of milk is usually about 0.75 per cent., but colostrum contains more than 1 per cent. of ash. Of the ash of normal milk one-fourth is potash (K_2O), another fourth lime (CaO), and one-fifth is phosphoric acid (P_2O_5), the remainder being magnesia (MgO), iron oxide (Fe_2O_3),

soda (Na_2O), and chlorine. Exactly how these are combined can only at present be surmised.

Average composition of colostrum and milk.

	Milk.	Colostrum.
	Per cent.	Per cent.
Water - - - -	87.85	73.40
Fat - - - -	3.40	3.40
Casein and albumin -	3.50	19.10
Milk sugar - - -	4.50	3.00
Ash - - - -	0.75	1.10

Causes of variation in the composition of milk.

The chemical composition of milk is affected by the following considerations: 1. Breed of cow, and strain of same breed; 2. time since calving; 3. climate; 4. treatment during milking; 5. period between milkings; 6. food.

1. **Breed of cow and strain of same breed.** Some breeds, such as *Ferseys*, *Ayrshires*, and *Dutch*, are milk producers, while others, such as *Sussex*, are mainly for beef production, milk being of secondary importance. The dual-purpose cow, that is, one satisfactory both as a milker and a beef producer, is still unknown, but the nearest approach to that ideal is perhaps the *Shorthorn*.

Some breeds, such as those of the Channel Islands, are essentially *quality* milkers, that is to say, the amount is not great, but the quality is excellent. Quality in milk is judged by the percentage of fat present, while quantity is merely the number of gallons produced. Some animals belonging to the heavy milking breeds do not come up to the usual standard, while others are exceptional in this respect. With regard to good milking strains, it can only be said at present that their progeny will in all probability inherit their milk-producing capacity, but there appears to be no certainty about it.

2. **Time since calving.** The milk drawn from a newly calved cow is known as **colostrum**, and differs from normal milk chiefly in the high proportion of albumin and ash present (see Table, p. 147). From three to fourteen days after calving, the milk has the composition of normal milk. Colostrum curdles on boiling; normal milk does not. Colostrum will not curdle properly on addition of rennet; normal milk will. Colostrum contains large corpuscles known as colostrum corpuscles (*corps granuleaux*), which are grape-like masses studded with drops of fat; normal milk does not contain such corpuscles. Colostrum, being highly albuminous, acts as a mild purgative, thus clearing out the intestines of the young animal.

The quantity yielded by animals gradually falls after the first month or so until the approach of the next calving, when usually the production ceases. There is, however, much variation in this respect.

The quality of the milk varies with the advance of lactation, but it may be taken as a general rule that the milk during the first and last month of the milking period is richest in both fat and solids not fat. It should be remembered, however, that, although rich during the last month, the quantity is small.

3. **Climate.** As might be expected, climate has some effect upon milk production. The delicate nervous system of the udder responds to changes in temperature in a remarkable degree. This is very noticeable when experimenting upon the feeding of animals for milk. A cold snap causes a material fall in the quantity of milk produced.

4. **Treatment during milking.** Cows being of a highly nervous temperament require quiet treatment during milking. It is well known that if a cow is ill-treated she holds up her milk. Again, a good milker takes care to empty the udder completely, and to carry out his work

with dispatch. Nothing tends more to reduce the milking capacity of an animal than rough treatment, slow irregular milking, or the work of a beginner in the art. The last milk drawn is always the richest; therefore it pays to milk clean.

5. **Period between milkings.** The longer the period, the poorer the quality of the milk. It has been ascertained by many careful experiments that if cows are milked twice per day at intervals of twelve hours, the milk is generally of the same quality, but if milked at intervals of, say, sixteen and eight hours, the milk after sixteen hours' interval is poorer in quality.

6. **Food.** The effect of food upon milk production has given rise to more controversy than any other single factor known to influence it. It is now generally accepted that food will influence the quantity but not the quality to any extent. A cow cannot be classed as a milking machine into which the more you put the more you get out. Each animal has its limit, especially as regards quality. If properly fed, she will produce milk of her own standard quality (provided, of course, she is properly housed and handled at the same time), but if improperly fed she may, and often does, fall below that standard. Careful experiments have shown that for every gallon of milk produced an animal should have 0.6 lb. of digestible albuminoids and 2.8 lbs. of carbohydrates (reckoned as starch). The further one departs from that ratio the greater the cost of production of each gallon of milk.

7. **Microscopical appearance of milk.** Under a low-power microscope, milk is seen to consist of a fluid or milk plasma studded with fat globules. The globules vary in size from 0.0016 to 0.01 mm. in diameter, their average being about 0.0035 mm. The number of globules present is very great. Careful counting has shown 3,000,000 per cubic millimetre (Fig. 46). The size and number vary

not only in milk from different breeds, but also in animals of the same breed and from the same animal.

Jersey milk is noted for its large globules; Ayrshire for small globules. The larger the globules, and the

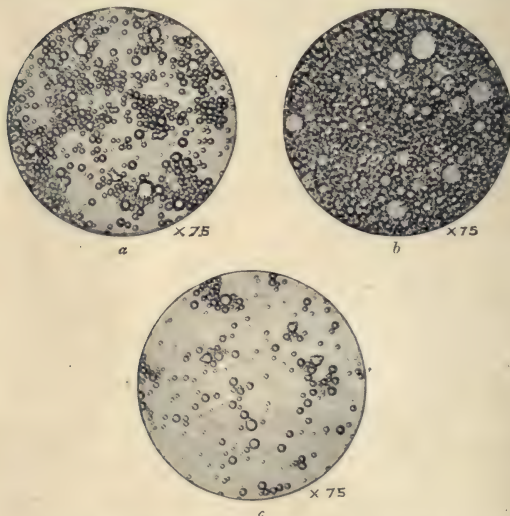


FIG. 46.—Microscopical appearance of (a) Cream, (b) Colostrum, (c) Milk.

higher the proportion of large globules, the quicker the fat rises to the surface on standing. The globules rise because their sp. gravity is lower than that of the milk plasma (0.92 against 1.034). Richmond has calculated that the largest fat globules rise at the rate of 15 mm. per hour, and that in twenty-four hours 85 per cent. of the fat present has risen to the surface. These figures are for

milk set in vessels approximately 1 ft. deep. Shallower vessels would, of course, give a higher percentage in the same time.

Adulteration of milk. Milk is a natural product varying greatly in composition, which very feature renders it very liable to adulteration. The chief extraneous substances added to milk are water, preservatives, and colouring matter. Fat may, however, be directly abstracted from new milk, or skim milk added to it; both materially depreciate the quality of the milk and at the same time lower its value as a food.

In 1901 and 1912 the Board of Agriculture issued regulations relating to the sale of milk. These regulations are cited as the Sale of Milk Regulations 1901 and 1912, and are as follows :

Milk.

1. Where a sample of milk (not being milk sold as skimmed, or separated, or condensed, milk) contains less than 3 per cent. of milk-fat, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1907, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk-fat, or the addition thereto of water.

2. Where a sample of milk (not being milk sold as skimmed, or separated, or condensed, milk) contains less than 8.5 per cent. of milk-solids other than milk-fat, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1907, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk-solids other than milk-fat, or the addition thereto of water.

Skimmed or separated milk.

3. Where a sample of skimmed or separated milk (not being condensed milk) contains less than 8.7 per cent. of milk-solids, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1907, until the

contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk-solids other than milk-fat, or the addition thereto of water.

According to the above regulations, genuine milk contains at least 3 per cent. of fat and 8.5 per cent. solids not fat. Any milk sold below this standard renders the seller liable to prosecution and to a penalty unless he is prepared to prove it is the genuine product of a cow or cows.

The unscrupulous producer or vendor may, therefore, tone down rich milk to the standard, while the honest man sells genuine rich milk at the same price. The obvious way out of this very unfair competition would be to fix the price according to the quality. This is done in many creameries where large quantities of milk are received daily; and if such could be arranged between the farmer and the retailer, the honest producer would be protected.

The fixing of a standard of 3 per cent. of fat enables one to calculate the deficiency in fat, should the percentage fall below 3 per cent.

Should the solids not fat fall below 8.5 per cent., a similar estimation of the deficiency can be made, and the probable excess of water present.

Example. A milk on analysis gives 2 per cent. fat and 8.9 per cent. solids not fat. What is the percentage deficiency of fat?

The sample should have contained 3 per cent. but actually contains 2 per cent. That is, out of a total of 3 parts fat 1 is deficient; therefore, out of every 100 of fat 33.3 is deficient, which is the percentage deficiency.

Out of 3 parts fat 1 is deficient.

$$\begin{array}{ccccccc} 1 & & & \frac{1}{3} & & & \\ 100 & & & \frac{100}{3} & & & = 33.3 \text{ per cent.} \\ & & & & & & \text{deficiency.} \end{array}$$

Again, if a milk is sold containing 2.8 per cent. of fat, that is, 0.2 below the standard, the deficiency, being a decimal, appears to be of little moment, but 0.2 per cent. deficiency out of 3 per cent., which the purchaser pays for, is 6.6 per cent. of his purchase.

The same remarks stand good as regards solids not fat. A milk containing 7.65 per cent. of solids not fat means a deficiency of 10 per cent. calculated as follows :

Out of 8.5 per cent. solids not fat there is a deficiency of 0.85.

1 per cent. solids not fat there is a deficiency of

$$\frac{0.85}{8.5}$$

100 per cent. solids not fat there is a deficiency of

$$\frac{100 \times 0.85}{8.5} = 10 \text{ per cent.}$$

This deficiency of 10 per cent. may be due, and occasionally is due, to the presence of added water ; but it is unfair to the farmer to state that added water is the cause of the deficiency, as cows have been known to produce milk deficient in solids not fat. It is, however, impossible for the farmer or vendor to abstract solids not fat ; therefore, unless the milk is from a cow producing abnormal milk, there is reasonable suspicion that water has been added. The addition of skim milk (provided it does not reduce the fat below 3 per cent.) cannot be detected, nor can the abstraction of fat unless carried out to such an extent that the sample falls below 3 per cent. It is obvious, therefore, that any statements as to deficiency only refer to deficiency below standard. The total abstraction could not be stated unless the original quality of the milk was known.

Stating the deficiency as a percentage of the total which should be present is preferred to stating merely the extent

to which it falls below 3 per cent., as it gives a much better idea of the actual loss to the purchaser.

Use of preservatives in milk. Milk is an important article of food for infants. As their digestive powers are not fully developed, very little preservative may, and does, seriously affect their health; and if for no other reason than this, preservatives should not be added. Primarily, preservatives were added to retard, or entirely to stop, bacterial action. In this they succeed more or less according to the amount added. When ingested the tendency is to check digestion, thus giving rise to stomach and intestinal troubles.

The addition of preservatives has, however, a much greater importance when considered from another point of view. Clean milk undergoes change in from 24 to 72 hours, depending upon its temperature, but dirty milk will not remain sweet for more than a few hours. Preservatives, therefore, hide the effect of dirt, and permit the sale of a contaminated product which would if unpreserved be unsaleable. The addition of preservatives to milk is illegal.

Colouring matter in milk. The important artificial colouring substances added to milk are annatto (a vegetable colour), and aniline dye (coal tar product). The latter turns red if the milk is rendered distinctly acid with hydrochloric acid, while annatto dyes a strip of filter paper salmon colour, when dipped in the milk after it has been rendered distinctly alkaline with sodium bicarbonate solution.

There is at present no law against the addition of colouring substances to milk. Those usually added are not deleterious to health (in the proportion usually present), but the artificial colouring of a natural product cannot be defended. The colour of milk is the only means the ordinary purchaser has of judging of its quality. The

addition of artificial colour deprives him of this ; therefore, purchasers should insist upon having natural milk.

Cream. When milk is allowed to stand for some hours a layer of fat collects on the surface which is known as cream. Until the advent of the separator, cream was always obtained by "setting" milk, that is, allowing it to stand in a cool place, until most of the fat had risen to the surface. The chief setting systems used could be classified under two heads: (1) the shallow system, (2) the deep system. These names refer to the depth of pan or vessel in which the milk was set. Shallow pans 4 to 6 inches deep and of a length and breadth depending upon the space available in the dairy were used for shallow setting, while deep setting pans were from 1 to 2 ft. deep and from 8 to 12 inches in diameter.

By the shallow setting system, less cream is obtained, but the quality is better, especially for butter making. The deep setting system, while giving more cream, does not impart to it such an excellent flavour as the shallow setting system ; and in addition, there is the disadvantage that any deep setting system requires abundance of very cold water, as quick cooling is necessary.

The two systems may be compared as follows :

Shallow setting system.

Deep setting system.

Slow rising of cream.
Butter yield not high.
Flavour excellent.
Skim milk apt to be sour due to length of time of setting.
Small volume of thick cream.
Much space for pans required.
Cold water not essential.

Quick rising of cream.
More butter from cream.
Flavour not perfect.
Skim milk sweet as time of setting is short.
Large volume of thin cream.
Economy of space.
Cold water or ice necessary.

The cream separator. If a bottle containing milk is allowed to stand over night, it will, due to variation in the specific gravity of the constituents of the milk, separate

into three layers: (1) dirt, found at the bottom of the bottle, (2) skim milk, (3) cream. If the bottle, instead of standing, is held by the neck and is revolved by means of a string or some mechanical contrivance, the same three layers will be obtained, but in much shorter time. The heavier the particles, the greater the tendency to fly outwards or away from the centre. Exactly the same

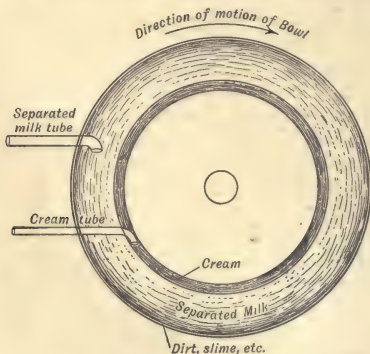


FIG. 47.—Cross section of separator bowl to illustrate the general principles of cream separation.

happens if a bowl or any vessel containing milk is rotated very quickly. A cross section of such rotating bowl indicates the principle of the separator (Fig. 47).

If conducting tubes facing in the opposite direction to the direction of rotation are dipped into the cream and separated milk respectively, as shown in Fig. 47, separation is easily effected. Various mechanical contrivances are used to split up the milk into layers, thus facilitating the separation of the fat, but the general principle of the separator is as above described.

In order that separation may take place in a reasonable time, the bowl must revolve between 5000 and 10,000 times per minute. The results are cream, and quite sweet, clean, separated milk. The separated milk is sweet because the milk has not had time to sour. Separated milk from good separators should contain less than 0.2 per cent. of fat; some machines leave only 0.1 per cent. or even less than this.

While separation adequately fulfils its duty as a mechanical creamer, the separated cream does not give such well-flavoured butter as the shallow system. This disadvantage is, however, outweighed by the numerous advantages of obtaining clean, sweet skim milk and lessening the labour entailed in shallow or deep setting systems.

Composition of cream. Cream has been analysed by the author containing 12 per cent. of fat, and one sample of milk as sold to the public was found to contain a higher proportion of fat. There is no standard for cream, but generally it contains between 25 and 60 per cent. of fat, although samples have been tested containing nearly 70 per cent. of fat. One remarkable property of cream is, although it contains so much more fat than milk, yet the ratio of solids not fat to water present is practically the same as in milk (see Table).

Composition of cream and milk.

			Cream.	Milk.
			Per cent.	Per cent.
Water	-	-	39.50	64.08
Fat	-	-	56.24	30.10
Solids not fat	-	-	3.87	5.26
Ash	-	-	0.39	0.56

The solids not fat have very closely the composition of the solids not fat in milk, while the ash shows little,

if any, variation from that of normal milk. The specific gravity of cream varies; the higher the per cent. of fat the lower the specific gravity, as shown below.

Specific gravity,	1.0035	Fat,	29.2 per cent.
" "	1.0090	" "	24.0 "
" "	1.0210	" "	13.7 "

Preservatives in cream. If preservatives are added to cream, the nature and extent of the addition must be plainly stated on a label fixed to the vessel in which the cream is sold. It is illegal to sell preserved cream without such a label. Regulations relating to this have been issued by the Board of Agriculture, an extract from which reads as follows:

Labelling of preserved cream. Every receptacle containing preserved cream must be labelled by the attachment thereto of an adhesive label. The size of the label must be as follows:

Not exceeding 1 pint	-	$\frac{3}{4}$ inch by $1\frac{3}{4}$ inch.
Exceeding 1 pint	-	3 inches by 5 inches.

Separated milk and skim milk. The separator produces a milk practically free from fat, as shown by the following analysis.

	Per cent.
Fat - - - -	0.15
Protein - - -	4.01
Milk sugar - -	4.70
Ash - - - -	0.75
Water - - - -	90.39

100.00 Sp. gravity about 1.035.

Skim milk, that is, milk skimmed by hand, contains a much higher proportion of fat. At present skim milk is rarely sold. Its composition depends upon the extent to which the cream has been skimmed, as well as the length of time the milk has been set.

The following may be taken as an average hand-skimmed milk :

	Per cent.
Fat - - -	0.70
Protein - - -	4.10
Milk sugar - - -	4.68
Ash - - -	0.76
Water - - -	89.76

100.00 Sp. gravity about 1.034.

QUESTIONS.

1. What is a mammal ? Name any farm animals which are mammals.

2. What are colostrum, new milk, skim milk, and separated milk? State their usual composition.

3. Describe briefly how you would estimate the percentage of fat, solids not fat, and the ash in milk.

4. From 5 gallons of milk containing 4 per cent. of fat, how much butter containing 10 per cent. of water could be obtained when the separator leaves 0.1 per cent. in the milk ? Take 1 gallon = 10 lbs. and neglect curd and salt.

5. What is the weight of 17 gallons of milk having a specific gravity of 1.032 ?

6. How would you ascertain the specific gravity of milk, and what use is it when known ?

7. A sample of milk gave the following figures on analysis : fat, 2.9 per cent. ; solids not fat, 8.7 per cent. What is the percentage deficiency of fat, taking as a basis for your calculation the standard fixed by the Board of Agriculture ?

8. If a milk contains only 8 per cent. of solids not fat, what percentage of added water is presumably present ?

CHAPTER X.

BUTTER.

PRACTICAL WORK.

1. Cut through half a pound of butter ; press it just above the cut surface, and note that liquid can be expressed.

2. Place a piece of butter about the size of a horse bean on clean platinum foil ; burn it until all carbon is consumed. Is any ash left ?

3. Melt 5 grams of butter in a small beaker ; pour off the fat. Note the curdy matter remaining. Transfer the curdy matter to a test-tube and treat it with soda lime. Test for ammonia, and from the result state whether butter contains nitrogen. Test about 1 gram of fat in the same way. Does it contain nitrogen ? What part of butter contains nitrogen ?

4. Heat 5 grams of butter in a porcelain dish over a naked flame until all crackling ceases. This only takes a few minutes. Find the loss in weight. This loss is water. Calculate the percentage.

5. Now just melt the fat ; then extract it carefully with successive small quantities of ether, pouring off after each extraction. *Remember ether must not be used near a naked flame.* When no more fat can be extracted dry and weigh the residue. The result is curd and salt. Calculate the percentage.

6. Boil the curd and salt with water. Filter the mixture ; estimate the common salt present by means of standard silver nitrate solution, using potassium chromate

as indicator. Subtract the common salt estimated from the curd and salt ; the difference is curd.

7. Weigh out 5 grams of butter ; melt it, and filter it through a hot filter paper into a 300 c.c. flask. (This is easily done by arranging paper and funnel in the hot air oven.) The fat filters through quite clear. Treat the fat with one gram of solid caustic soda and 10 c.c. of alcohol. Heat the mixture for a few minutes on the water bath until all the fat is dissolved. Test the product when dry, and describe its character. Dissolve it in 100 c.c. of hot water ; then add 40 to 50 c.c. of dilute sulphuric acid and distil off, say, 100 c.c. Test whether the distillate is acid. Does butter contain volatile acid or acids ? Were they added to the butter ? If not, then they were present in the original sample, not free, but combined ; the treatment liberated them.

8. Now treat a sample of margarine in the same way. Note that the distillate is not nearly as acid, but is slightly acid. If you had estimated the acids present by titrating with N/10 caustic soda, the distillate from the butter would require at least five times as much N/10 caustic soda to neutralize it as the distillate from the margarine did. Try this.

Legal definition of butter. The Margarine Act of 1887 defines butter as "the substance usually known as butter, made exclusively from milk or cream or both, with or without salt or other preservative, or with or without the addition of colouring matter," while margarine is defined as "all substances whether compounds or otherwise prepared in imitation of butter and whether mixed with butter or not."

When cream is shaken in a bottle or churn, the globules of fat coalesce to form butter. Various theories have been advanced to explain the production of butter, the one usually accepted assigning the cause to the impact of one globule upon another, thus squeezing out the intervening liquid, and bringing them near enough for

coalescence to take place. This widely accepted theory assumes that the fat globules are surrounded by something which is sufficient to resist any ordinary impact. During churning the force of concussion overcomes the separating layer or medium.

Cream when quite fresh, that is, sweet, may be churned into butter. The product, however, has not the flavour of ordinary butter ; and as there is only a limited market for it, very little, if any, is made in England. Ripened cream, that is, cream which has soured, is generally used in England. The exact point to which ripening should be carried before churning, can at present be judged better by an experienced butter-maker, than by accurately estimating the acidity or sourness by chemical means.

The advantages of sour cream for butter-making are as follows :

1. The butter has better flavour.
2. More butter is said to be obtained from a given quantity of cream.
3. Churning is more easily carried out.

Ripening of cream. The ripening or souring of cream is brought about by bacteria, different species of which have different effects upon cream. These bacteria may be roughly classified as follows :

1. Favourable to the manufacture of butter.
2. Neutral or doubtful.
3. Unfavourable.

The favourable organisms usually predominate ; therefore, butter is generally of fair quality, if the dairy is kept clean. If, on the contrary, the utensils and dairy are not perfectly satisfactory as regards cleanliness, the unfavourable organisms outnumber the favourable, and tainted butter is the result.

Favourable organisms generally predominate because they are the type commonly found in clean dairies ; also,

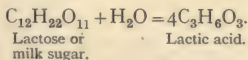
the external conditions in well-kept dairies are more satisfactory for their growth, and they are generally more vigorous than the others.

If it should happen that a dairy becomes contaminated with unfavourable organisms, the only course to pursue is to clean it thoroughly, and to recommence cream ripening with a little cream from a dairy producing excellent butter. Also, it is an advantage to retard the growth of any unfavourable organisms present in the cream by heating it to 155° F. This is known as **pasteurizing** the cream, and is so called after the celebrated French bacteriologist and chemist, Louis Pasteur.

At present, it is possible to purchase growths, or as they are called, **cultures**, of good butter-producing organisms, which when added to cream ripen it as perfectly as can be done in the circumstances.

Generally, the growth of these added cultures is so vigorous that they outnumber the unfavourable organisms, producing a ripened cream which, in turn, gives a well-flavoured butter. The preparation of pure cultures is the work of experienced bacteriologists, and is not undertaken in ordinary dairy practice. The advantages of cultures in butter-making are: (1) the butter-maker can regulate the ripening, (2) the butter is more uniform in quality, (3) the flavour is usually improved.

Chemistry of cream ripening. Cream contains water, protein, milk sugar, and ash, in addition to fat. The milk sugar, when acted upon by certain organisms (favourable organisms) known as **lactic acid bacilli**, is chemically changed into lactic acid. The equation expressing this change is as follows :



It is this acid which is the actual cause of the sourness

of ripened cream. It must not, however, be thought that the ripening of cream is altogether explained by the above simple chemical change. If such were the case, then the addition of the necessary amount of lactic acid would be a simpler and more expeditious method of ripening cream than the "setting" for ripening to which cream is usually subjected. Various intermediate products are produced at the same time, all of which take a part at present not explained in the production of perfectly ripened cream.

Again, the nutty taste of good butter is certainly not due either to milk sugar or lactic acid produced therefrom, but appears to be a product of the protein (casein) always present in cream. Anyone who has tasted the carefully dried non-fatty solids of milk and cream cannot fail to detect the similarity which exists between the taste of the non-fatty solids and good butter. Evidently, therefore, the solids other than fat take some part in the production of well-flavoured butter. That such is the case is borne out by the fact that, if butter is washed excessively with water, the flavour practically disappears.

Temperature of cream for churning. The temperature of cream prepared for churning varies between 54° and 65° F. There is no standard temperature for churning. The experienced butter-maker is able to decide by taking into consideration the temperature of the dairy and the churn, the kind of cows kept, the food used, and the ripening of the cream, at what temperature it is best to churn; but as a useful guide the following temperatures should be noted:

If temperature of air is 55° F. churn cream at 60° F.

"	"	58°	"	"	59°
"	"	60°	"	"	58°
"	"	62°	"	"	57°
"	"	64°	"	"	56°
"	"	66°	"	"	55°

Churning of cream. Churns vary in size and shape, but experience has proved that from the point of view of easy working and cleanliness, a cylindrical churn possesses many advantages and few disadvantages. All churns are provided with removable cream-tight lids, a valve to allow of the escape of the gases (liberated during churning), and a hole near the bottom which, when the churn is in use, is closed by a bung or plug.

The size varies with the amount of cream to be churned. A small churn two-thirds full does not give such good results as a larger churn one-third full; the best proportion is a churn about half filled. The pattern generally used is known as the end-over-end-cylindrical churn, which name explains not only the shape but also the method of usage.

The speed at which a churn is rotated to get the best results is largely a matter of experience, but generally varies between thirty and sixty revolutions per minute; although when watching competitive butter-making tests at the Dairy Show at Islington, one is compelled to admit that there are very wide variations in the revolutions per minute.

Churning is continued until the cream breaks; that is, until small grains of butter are produced. Further churning will produce larger grains, or, if continued too long, the whole may be churned into a lump; but this is always avoided by the best butter-makers, because, when lumps are produced, there is great difficulty in pressing out the liquid (butter-milk). If the process is only continued until large grains are produced, most of the butter-milk can be drained off; less pressing or working is required, and a finer grained butter results. After straining off the butter-milk, the grains are worked either by hand or by a butter-worker, care being taken not to over-work the grains, otherwise a greasy product is the result.

Washing the grains with brine while in the churn, or dry salting on the worker, is usual, the extent to which this

is carried out depending upon the degree of salinity required in the finished product. Salt is added not only for flavouring but as a preservative. Salt butter keeps for many weeks, while unsalted butter undergoes change, soon becoming too rancid to eat.

Butter-milk. The liquid drained off from the grains of butter produced during churning varies greatly, the composition depending upon the perfection of churning. A sample analysed by Fleischmann gave the following figures:

Water	-	-	-	-	91.24 per cent.
Fat	-	-	-	-	0.56 „
Protein	-	-	-	-	4.00 „
Milk sugar	-	-	-	-	3.50 „
Ash	-	-	-	-	0.70 „

Preservatives in butter. The usual preservatives added to butter are boric acid and borax, or mixtures of the two; but alkaline fluorides have been and are still occasionally used. The Departmental Committee on Food Preservatives recommended in 1901 that boric acid in butter should not be used in greater proportion than 0.5 per cent., that is to say, 35 grains per lb. Consequently, objection is not usually taken to the presence of boric acid unless it exceeds this amount.

Composition of butter. Good butter contains between 8 and 13 per cent. of water, 1 per cent. of curd, and 1 per cent. of salt, the remainder being genuine butter fat. The following numbers give some idea of the various grades:—

Composition of Butter.

Sample.	Water.	Fat.	Curd.	Salt.	Quality.
	Per cent.	Per cent.	Per cent.	Per cent.	
1.	8.65	89.33	1.10	0.92	Good ; high class.
2.	12.75	84.20	2.05	1.00	Fairly good
3.	14.26	80.84	3.70	1.20	Fair
4.	16.82	76.36	4.72	2.10	Low grade.

Relation between fat in milk and butter produced.

If milk contains 3.5 per cent. of fat, then 100 lbs. of milk would produce 3.5 lbs. of butter if the butter consisted entirely of fat. Butter, however, contains water, curd, and salt, which taken together generally amount to, say, 12 per cent. Therefore, in 100 lbs. of butter, 12 lbs. are water and solids not fat, and 88 lbs. of fat are present in the 100 lbs.

Or, 88 lbs. of fat therefore gives 100 lbs. of butter.

1 lb.	"	"	"	$\frac{100}{88}$	"	"
3.5 lbs.	"	"	"	$\frac{350}{88}$	nearly 4 lbs.	

A milk containing 3.5 per cent. of fat will produce nearly 4 lbs. of butter for each 10 gallons, provided there is no loss. The separator, however, does not entirely remove the fat, but the amount is generally negligible. Again, in butter-making, the butter-milk is not free from fat, the amount depending greatly upon the experience of the butter-maker.

Theoretically, a milk containing 3.5 per cent. of fat should from every 100 lbs. (say 10 gallons) give 4 lbs. of butter, that is, 1 lb. from every $2\frac{1}{2}$ gallons. The better the quality of the milk the less the amount required to produce 1 lb. of butter.

QUESTIONS.

1. What is butter? State its usual composition.

2. If $2\frac{1}{2}$ gallons of milk will produce 1 lb. of butter and a gallon of new milk is worth, say, 9d., what should be the lowest value of a lb. of butter? (This allows nothing for the separated milk. If you deduct the value of the separated milk from $2\frac{1}{2}$ gallons of new milk, you then have the net value of 1 lb. of butter. What the farmer gets above this would be payment for the making.)

3. Take into consideration the figures in Question 2. Which would be more remunerative, to sell 10 gallons of

milk at 8d. per gallon, or separate it and make butter which sells at 1s. 3d. per lb. ?

4. What is meant by the " ripening " of cream ?
5. Butter-milk varies greatly in different dairies. Explain this.
6. Discuss the relation which exists between the percentage of fat present in milk and the quantity of butter produced therefrom. Why is a similar relationship not possible between the percentage of cream present and the amount of butter produced ?
7. Are you aware of any foods which affect (a) the quality of the butter, and (b) the quantity produced by a herd of cows ? If so, name them.

CHAPTER XI.

CHEESE.

PRACTICAL WORK.

1. OBTAIN specimens of various kinds of cheese, and note any peculiarities, such as colour, hardness, mouldiness, etc.

2. Grate a few grams of Cheddar cheese. Weigh out five grams in a porcelain basin. Dry it in the air oven at 105°C . Incline the dish to expose the curdy matter to the hot air. Weigh the dish and its contents at intervals. When constant weight is obtained, calculate the percentage of water.

3. Extract the residue with ether (observing the usual precautions when using ether), and when complete, dry it, weigh the curdy matter, and calculate the percentage.

4. Reduce to ash about two grams of cheese and estimate the percentage of ash. Add together the water and curd (which contains the ash); the difference is the fat.

5. Treat half a gram of cheese in a test-tube with soda lime; note if ammonia is produced. What constituent of cheese contains nitrogen?

Cheese. There is no period in the history of man in which cheese making was not known; but even now the chemistry of the subject is very imperfectly understood. The fact that an extract of the dried stomach of a calf possesses the power of curdling milk appears to have been known in very early times. Until about the middle of the nineteenth century, the action of the extract was stated to

be due to the production of acid generated by the extract. In 1840 Berzelius, a Swedish chemist, proved that curdling took place independently of any acid production. Later, curdling was shown to be the result of the action of an enzyme known as **chymosin**, commonly called **rennet** or **lab**. Rennet is found in the stomach of many farm and other animals and birds, and in vegetable juices. Its exact constitution is not known. If a calf's stomach is exposed to the air until dry, then powdered and extracted with brine, an extract of rennet is obtained which will curdle milk. Rennet in liquid, powder, or tabloid form can now be purchased.

Acids will also curdle milk, but the curd produced by acids differs from that produced by rennet in two important particulars, namely: (1) the bacteria present in acid curd differ remarkably from those in rennet curd, and as a consequence have an important influence upon the ripened curd, that is, cheese. (2) Acid curd is fluffy and non-contractile, while rennet curd is more solid and is very contractile. Contraction of the curd assists in the expression of the liquid known as **whey**.

Cheese-making. If to a pint of slightly warm milk rennet is added and well mixed with the milk, curdling will take place in from five minutes to half an hour, depending upon the amount of rennet added and the condition of the milk when renneted. If the liquid portion (or whey) is run off and the curd broken up, salted, and pressed, crude cheese is obtained. To complete the process the crude cheese would have to be kept for some weeks in a room the temperature of which is carefully regulated. It would then mature or ripen, thus producing cheese.

The above process appears very simple, but cheese-making is far from being a simple process. Every external and internal condition to which the milk is subjected

during the process affects the resultant product: the temperature of the milk, the amount of rennet added, the time allowed to act, the cutting of the curd, the grinding, salting, pressing, and ripening, all play their part.

Only experience can teach how to produce good cheese, and even the work of experienced hands occasionally ends in dismal failure. There is no royal road to the subject, and if "experience teaches" can be truthfully applied to any branch of dairy work, that branch is surely cheese-making.

Different kinds of cheese. A simple classification of the various kinds of cheese sold in England is as follows:

1. **Cream cheese** (from cream only).

2. **Soft cheese**: Brie, Camembert, Pont l'Évêque, Neufchatel, and Bondon. These are made from whole milk; Gervais and Pommel are soft cream cheeses. All these are prepared from cows' milk by the action of rennet. Strachino is an equivalent Italian cheese.

3. **Hard cheeses**. Fat is removed to some extent from the milk from which the cheese is prepared. Gloucester, Derby, Leicester, Edam, and Gruyère are hard cheeses; while Parmesan is an Italian cheese similarly made. These cheeses are, as above stated, usually made from partly-skimmed milk, although some are also made from whole milk.

4. **Whole-milk cheeses**: Cheshire, Cheddar, Wensleydale, Port de Salut, Emmenthaler, and Gruyère (sometimes), Gorgonzola and Cacio Cavallo.

5. **Skim-milk cheeses**: Dutch and York. Roquefort is a cheese made from sheep's milk.

Composition of various cheeses.

Name.	Water.	Fat.	Ash.	Protein.
	Per cent.	Per cent.	P. cent.	Per cent.
Cheddar, av. of 5 samples (English) -	32.5	29.6	4.0	29.2
Cheddar (American), av. of 5 smpls.	30.3	29.2	3.7	33.8
Gorgonzola, av. of 3 samples -	38.3	28.2	4.7	25.8
Gruyère, „ 3 „ -	33.3	29.8	4.0	30.2
Stilton, „ 3 „ -	25.2	40.6	3.0	23.8
Gloucester, „ 3 „ -	35.9	24.8	4.7	31.2
Cheshire, „ 3 „ -	36.2	32.4	4.1	25.3
Dutch, „ 3 „ -	38.9	19.2	6.1	31.3
Camembert, „ 4 „ -	46.8	30.5	4.1	21.1
Cream, „ 2 „ -	39.0	59.6	2.1	11.0
Gervais, „ 3 „ -	42.72	45.1	1.31	9.1
Parmesan (goats' milk) „ -	30.8	19.60	5.92	41.82
Roquefort (ewes' milk) „ -	29.6	30.3	6.7	28.3

Composition of whey.

	Water.	Fat.	Ash.	Protein.	Milk Sugar.
	Per cent.	Per cent.	P. cent.	Per cent.	Per cent.
Analysis by Fleischmann -	93.15	0.35	0.6	1.0	4.9

Whey consists chiefly of water and milk sugar, in fact, milk sugar can be most easily obtained from whey by evaporation.

Adulteration of cheese. There is no standard for cheese, and, as a consequence, inferior quality cheeses are sold under names which should only be used for finest quality samples. Cream cheeses have been analysed containing little more fat than skim-milk cheeses. Occasionally “filled cheeses” are sold as genuine cheese. A filled cheese has had margarine substituted for milk fat. This is gross adulteration, and is treated as such under the Food and Drugs Act. Margarine cheese is a perfectly wholesome article of food, and if sold under its proper

name no objection can be taken to it. The detection of margarine in cheese necessitates the extraction of the fat, and a complete analysis to determine its chemical and physical constants.

CHEESE.

1. How is cheese prepared ? What is rennet ?
2. What are the chief constituents of whey ?
3. State briefly the important factors which influence the quality of cheese.
4. What are cream cheese, whole-milk cheese, skim-milk cheese, and filled cheese ? State the percentages of fat and protein found in good samples of the first three.
5. How would you extract the fat from cheese ?
6. What are bacteria ? Mention any part they play in cheese-making.
7. What is meant by the ripening of cheese ?
8. Acids will curdle milk, but are not used in cheese-making ; why ?
9. How much cheese would you expect to get from two gallons of milk ?

CHAPTER XII.

INSECTICIDES AND FUNGICIDES.

FARM and garden crops are subject to damage by insects, fungi, and other pests. Some insects do harm by gnawing the stems, leaves, and roots; while others puncture the epidermis and suck the juices. Fungi, which belong to a group of simple forms of plants, often do injury by living parasitically upon their host plants. To prevent or combat these attacks, various solids, liquids, and gases are employed, and are designated **insecticides** and **fungicides** respectively.

The various substances used to combat the various pests may be roughly classified according to their effects as those which :

1. Prevent insect and fungoid attacks.
2. Directly poison insects (or their larvae) during the attack.
3. Kill by acting mechanically upon the insects.

Insecticides.

Preventives. It may be taken as a general rule that anything which tends to promote the health of a crop is a preventive. Good tilth, vigorous seed, judicious manuring, suitable rotation of crops, freedom from weeds and rubbish—all play their part, while the preservation of insect-eating birds should not be overlooked.

In orchards, cleanliness of the bark of fruit trees is of extreme importance, as lichens and mosses form very suitable breeding places for injurious insects.

But even when all the above preventive measures are taken, attacks may still take place. Therefore it behoves the farmer and gardener to employ any artificial means which may be to hand to ward off impending attacks. The most important are stated below. It should be mentioned that although the following are classed as preventives, they may in certain cases act as remedies. It is really very difficult to draw the line between preventive and remedial measures; what is a preventive of one attack may be a remedy for another.

Important artificial preventives. Lime. This in the form of whitewash is probably one of the oldest remedies for cleaning the bark of trees. While getting rid of lichens and mosses it undoubtedly in many cases also destroys the eggs of injurious insects present on the bark and in other cases the actual insects themselves. The presence of a little salt is said to increase the adhesiveness of the wash.

Caustic soda and carbonate of potash spraying fluid. This spraying fluid is easily made by dissolving 1 lb. of carbonate of potash and 1 lb. of caustic soda in 5 gallons of water. To this add 5 gallons of a solution of $\frac{1}{4}$ lb. of soft soap in 5 gallons of water. Mix the solutions, and use as a winter spray for cleaning the bark of fruit trees.

Quassia and soft soap. If 1 lb. of quassia chips be extracted with 5 gallons of boiling water to which has been added $\frac{1}{2}$ lb. of soft soap, and after pouring off the extract, the process be repeated with a fresh quantity of water and soap, a total extract of approximately 10 gallons is obtained. This forms a very useful preventive wash for insects which attack the leaves of trees, as well as a suitable wash for the destruction of aphides on all crops.

Grease banding. Apple, pear, and plum trees are liable to attacks by the larvae of insects whose eggs have been deposited in the cracks in the bark of the trees. The larvae of various species of winter moth are very troublesome in this respect, as the eggs having been laid in autumn are ready to hatch in the following spring, and, what is of more importance, when hatched ready to attack the young, delicate, unfolding buds. The female winter moth climbs the stem or trunk and lays her eggs in the crevices in the bark. To check her ascent, various sticky greases are placed round the stems, the process being known as **grease banding**.

Grease liable to affect the bark should be placed on grease-proof paper and the paper tied round the tree, care being taken to leave no channel through which the moths can ascend.

Toxic remedies. Mineral toxic remedies usually contain arsenic in some form or other. The most important are Paris green, lead arsenate, and London purple. Paris green is copper acetoarsenate, $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_3\text{CuAs}_2\text{O}_4$, lead arsenate is PbAs_2O_4 , while London purple is a mixture of calcium arsenate and arsenite coloured by the purple dye from which it is prepared.

Paris green in the proportion of 1 oz. to 10 gallons of water is applied in the form of a fine spray as a remedy for caterpillars. Lead arsenate, $1\frac{1}{2}$ oz. to 10 gallons of water, is also used for the same purpose, while London purple spraying fluid may be prepared in the same proportion as the Paris green fluid.

Care should be taken in using all arsenical compounds, as they are decidedly poisonous.

Organic toxic remedies. The important remedies of this type are powdered hellebore, pyrethrum powder, tobacco, and carbolic acid.

Hellebore is used in the proportion of 2 lbs. to 10 gallons

of water. Pyrethrum powder is used in the same proportion, while tobacco leaf is boiled for half an hour with water and afterwards strained through cloth. The proportion used is $\frac{1}{2}$ lb. to 12 gallons of water. All the above are used for the same purpose as the arsenical washes. Carbolic acid in the proportion of 1 pint to 50 gallons of water, plus 1 lb. of soap, is often used to destroy maggots affecting radishes and onions.

Contact remedies. These kill the important sucking insects by actual contact. They clog the breathing pores of the insect or kill by their corrosive action.

Sulphur; lime, sulphur, and salt; paraffin emulsion; and methylated spirit are the important contact sprays.

Sulphur was much used many years ago as a dusting powder to kill or check insect and fungoid attacks. At the present time it is superseded by the lime, sulphur and salt wash, which is prepared as follows. To 3 lbs. of lime and $3\frac{1}{2}$ lbs. of sulphur add 5 gallons of water and boil for one hour. Add to this 3 lbs. of lime, 3 lbs. of common salt, and 5 gallons of water. The fluid is used either as a winter wash or for killing red spider and also insect pests of fruit trees.

Paraffin emulsion. Paraffin emulsion contains 2 gallons of paraffin to 1 gallon of water and $\frac{1}{2}$ lb. of soft soap. This is the stock solution. It is used in various strengths for different purposes. For woolly aphids it may be used 1 part in 2 of water. For spraying hardy plants, 1 in 40 to 1 in 50; while as an insecticide, 1 in 25 to 1 in 30 is generally used.

Methylated spirit. This liquid, which is alcohol plus about 10 per cent. of wood naphtha, is usually applied with a brush as a remedy for American blight.

Fumigants. Fumigants, such as prussic acid and carbon bisulphide, are largely used in greenhouses, frames, etc.

For outdoor use, special apparatus is necessary, as the fumes must be confined if their full effect has to be felt.

Hydrocyanic acid or prussic acid. Hydrocyanic acid is usually prepared on the spot by treating potassium or sodium cyanide with sulphuric acid. One oz. wt. of potassium cyanide, if treated with 1 fluid oz. of sulphuric acid and 3 fluid oz. of water, will suffice for 150 cubic ft. of confined space. The water should be placed first in a pan or crock; the sulphuric acid is then added, and finally the potassium cyanide. The fumes are very poisonous to human beings, in fact to all animals; therefore *immediately the cyanide is added, the operator should leave the confined space.*

Outdoor fumigations are carried out under a sheet or tent specially designed for the purpose.

Carbon bisulphide, CS_2 . This liquid is used in the proportion of 1 pint for every 900 or 1000 cubic feet. It is easily inflammable, *and should never be used near a flame or even hot metal.* The vapour is given off spontaneously, and as it is very heavy, there is a tendency for it to accumulate near the ground in any enclosed space, and would ignite if it came in contact with any flame. As a soil fumigant it has been to some extent used, and also for killing weevils in grain.

Soil fumigants. Various proprietary compounds are placed on the market as soil fumigants. There is no doubt that these serve their purpose, being especially useful in checking the attacks of wireworms.

Fungicides. Fungi live parasitically upon many farm and garden crops. The damage done is very great; therefore any means of avail in checking their ravages deserve full consideration. For more than a century it has been known that a solution of copper sulphate has marked fungicidal properties; in fact, it can be stated

that most fungicides contain copper sulphate in a greater or less proportion.

The important fungicides in use at the present time are: copper sulphate; copper sulphate and lime (Bordeaux mixture); copper sulphate and carbonate of soda (soda Bordeaux, or Burgundy mixture); formalin; and liver of sulphur.

Copper sulphate, CuSO_4 (bluestone). This has been used for many years to kill the spores of smut of corn. Later experiments, however, have proved that it is not until the spores commence to germinate that the effect of copper sulphate as a smut destroyer is to any extent very marked. The compound appears to be quite deadly to the germinating spores although practically without effect on the actual spores. For this purpose a 10 per cent. solution of copper sulphate is used, that is, 1 lb. in 1 gallon of water. One gallon of this solution would be sufficient to treat, say, half a quarter of grain.

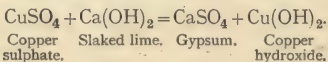
Formalin. This is a 40 per cent. solution of formic aldehyde, CH_2O ; 1 pint to 40 gallons of water forms a useful solution for pickling grain to check the action of smut; also for potato scab. Immersion for from 15 to 20 minutes is necessary. About 1 gallon of the mixture is required per bushel of grain.

Bordeaux mixture. This spray fluid, which is chiefly used as a preventive against potato disease or blight, is not a definite compound; so a chemical formula cannot be assigned to it. It takes its name from the city of Bordeaux in France, where it was first used in the vineyards of the district to check the action of fungi on the vines. The mixture is prepared by dissolving copper sulphate in water and adding slaked lime (also dissolved in water) until the liquid is slightly alkaline. Various proportions in which the ingredients should be mixed are given in text-books. The proportions no doubt are quite satisfactory when the actual composition of the two

ingredients is known, but both commercial copper sulphate and lime vary to such an extent that it is not always possible to get the best results by always using one formula. Three well-known formulae for making Bordeaux mixture are : Copper sulphate 8 lbs., lime 4 lbs., water 40 gallons ; copper sulphate 6 lbs., lime 4 lbs., water 40 gallons ; and copper sulphate 4 lbs., lime 4 lbs., water 40 gallons.

It is obvious, therefore, that if the first is correct, the second and third contain excess of lime. The following method of preparation will, however, overcome the difficulty as regards too little or too much lime, and should always be carried out if the composition of the lime is unknown. Take from 7 to 8 lbs. of copper sulphate powder (at least 98 per cent. pure). Suspend it in a coarse sack in a wooden barrel or earthenware vessel containing 20 to 30 gallons of water. Leave it there overnight, when the copper sulphate will usually be completely dissolved. Slake 6 lbs. of fresh lime, and after completion mix with 8 to 10 gallons of water, and stir well. When ready to carry out the spraying add the milk of lime to the copper sulphate solution until the mixture after stirring is faintly alkaline. Make up to 40 gallons and use at once for spraying purposes, taking the necessary precaution to strain through sacking before putting it in the spraying machine.

The reason for this careful preparation is as follows. Copper sulphate is an acid salt ; therefore, if applied in solution to foliage, scorching will result. The addition of lime neutralizes the acidity, and if the solution is rendered alkaline, results in the formation of copper hydroxide in accordance with the following equation :



It is the precipitate of copper hydroxide which gives to Bordeaux mixture its sky-blue colour ; in fact, this sky-blue colour is sufficient to guide the constant user of it as to enough lime having been added.

The copper hydroxide has little or no effect upon fungoid growth, but when applied to crops the carbon dioxide given off by the leaves reacts with the copper hydroxide, forming a compound with marked fungicidal action.

The fluid is applied in the form of a fine spray at the rate of 100 to 120 gallons per acre for one dressing.

Precautions to be observed in making Bordeaux mixture.

1. Use the very best copper sulphate obtainable for the purpose.

2. Add lime until the mixture is alkaline. (Prove this either by using a piece of litmus paper or by dipping a *clean* steel knife blade into the mixture. If the knife appears coppery after immersion for three minutes, more lime is needed.)

3. Use the mixture as soon as prepared.

4. Use wooden buckets and tubs, as copper sulphate acts upon zinc pails.

Bordeaux mixture is chiefly used for checking potato disease, and for fungi attacking the foliage of fruit trees.

Soda Bordeaux (Burgundy mixture). This is made in exactly the same way as Bordeaux mixture, and is used for the same purposes. It has the advantage of being more easily prepared. Instead of lime, washing soda (carbonate of soda) is used, 8 lbs. of copper sulphate requiring about 10 lbs. of washing soda.

Liver of sulphur, K_2S . A freshly prepared solution is used as a remedy for gooseberry mildew ; while a 1.5 per cent. solution is used for dressing corn to prevent smut. It has, however, been superseded by the various copper fungicides already mentioned. Special care should be taken to use the solution when freshly made, as on

exposure to the air it undergoes oxidation, thus losing strength.

QUESTIONS.

1. Distinguish between insecticides and fungicides; and between insects and fungi.

2. Give the usual methods employed for the *prevention* of insect and fungoid attacks.

3. Write a short essay on "The effect of climate on fungoid attacks."

4. In order successfully to combat insect attacks the life-history of the insect must be known. Why?

5. Name the chief toxic insecticides, and mention the usual strength of the solution of each used.

6. Can you give any reason why a toxic insecticide should not contain free trioxide of arsenic (As_2O_3)?

7. What are the advantages and the disadvantages of fumigation as a means of remedying insect attacks?

8. State the usual precautions necessary in using hydrocyanic acid or carbon bisulphide.

9. What quantity of potassium cyanide would be required to fumigate a building 15 ft. long, 8 ft. wide, and of an average height of 8 ft. 6 in.

10. What is Bordeaux mixture? How is it prepared, and for what is it principally used?

11. How is Burgundy mixture prepared, and what are its advantages over Bordeaux mixture?

12. It is required to spray 4 acres of potatoes three times with Burgundy mixture. Calculate the amounts of copper sulphate and washing soda that would be required for the purpose.

ANSWERS

Page	19.	No.	4.	28 lbs.
"	97.	"	5.	Sulphate of ammonia, 4d. per unit.
"	119.	"	2.	8.5 % of oil and 16.4 % of albuminoids.
"	138.	"	15.	117 food units, 1s. 4½d. per unit.
"	"	"	18.	£8.
"	159.	"	4.	4.3 lbs. per 10 gallons, or 2.15 lbs. per 5 gallons.
"	"	"	5.	175.4 lbs.
"	"	"	7.	3.3 % deficiency.
"	"	"	8.	5.87 % of added water.
"	167.	"	2.	1s. 10½d. per lb.
"	"	"	3.	Sell the milk.
"	182.	"	9.	6.8 ozs. of potassium cyanide.
"	"	"	12.	240 lbs. of copper sulphate, and 300 lbs. of washing soda, at 100 gallons per acre.

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